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Measurement of Work Processes Using Statistical Process Control: Instructor's Manual

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Measurement of Work Processes Using Statistical Process Control: Instructor's Manual

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Approved and released by
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FOREWORD

This technical note contains the instructional materials for trainers of basic statistical methods used in process quality control. The training materials were developed as a classroom aid for implementing the statistical methods and techniques described by Ishikawa in his Guide to Quality Control; they were designed to teach managers and workers in Navy industrial activities these methods. Research for this work was sponsored by the Chief of Naval Operations (OP-04) with program element PE63739N. Claimant for this work was established within the Naval Supply Systems Command (PML5505). Support for courseware and workshops developed for test and evaluation was provided by the Naval Civilian Personnel Command (CEEP Code 02) with work request N0002385WR55N44.

Appreciation is expressed to the commanding officer and his staff at the Naval Air Rework Facility, North Island, California for providing the developmental testbed for these materials. Appreciation is also extended to University Associates Publishers, Inc., which kindly granted permission to reproduce information concerning a group exercise described in The 1975 Annual Handbook for Group Facilitators (La Jolla, California, 1975).

Requests for information concerning this work should be directed to Steven L. Dockstader, Navy Personnel Research and Development Center.

RICHARD C. SORENSON
Director, Human Performance Department

SUMMARY

This report contains the instructor's manual for the course Measurement of Work Processes Using Statistical Process Control. The course was developed for Naval Air Rework Facility personnel by the Performance Management Division, Human Performance Department, Navy Personnel Research and Development Center (NAVPERSRANDCEN) to introduce statistical process control techniques for measuring work processes.

Statistical process control (SPC) is a methodology that can be used to help improve any work process from manufacturing to paperwork. It maximizes product quality through control of work processes rather than through postproduction inspection. Statistical process "control" involves identification and removal of systemic causes of defects and reduces the variation in the critical process components. Once a process has attained a state of statistical control, it is expected as a result of systematic management action to create consistently defect-free products or services. Products and services without defects eliminate waste and rework costs, minimize inspection costs, and lead to increased productivity.

The SPC methodology includes the following activities: (1) problem identification, (2) data collection, (3) data summarization and graphic presentation, and (4) recommendations and changes to be implemented based on the data. This approach is cyclical in nature and is often referred to as the Plan-Do-Check-Act (PDCA) cycle by management specialists.

Simple statistical tools are available that help to describe processes and display important process data in such a way that problems become more readily apparent and solutions easier to determine. Seven of these are treated here. They include flow charts, cause-and-effect diagrams, Pareto diagrams, histograms, scatter diagrams, run charts, and control charts. These graphics aid in identification of potential problem areas. Displaying and analyzing data in graphic format helps one to make decisions and take actions based on data rather than on speculation or guesses.

Course Objectives

The course is part of a quality management training package developed at NAVPERSRANDCEN. The package emphasizes an approach that helps students to understand work flow, to identify sources of work process problems, to initiate changes to minimize the impact of these problems, to evaluate the effect of these changes, and to continue activities that minimize system or process difficulties. The objectives of the course are to familiarize the student with structured problem solving and the basic graphic methods, to show the student when and how to apply the basic graphic methods, and to give "hands-on" experience with these methods.

Course Description

The course is comprised of 10 sessions. Each session is divided into two parts, a lecture presentation and a hands-on, problem-solving laboratory. In the lecture portion of each session, guidance is provided for the use of each of the seven graphic methods--how to construct them, when to apply them, and how to interpret them. The methods are presented as tools to be used within the framework of the PDCA cycle. During the lab portion of each session, the student practices construction of a particular method and application of it to job-specific examples. Viewgraphs are provided for all sessions.

Organization of Instructor's Manual

The instructor's manual has three major sections. The first section, Part I, the Introduction, briefly reviews the basic concepts of process control systems, process variation, and continuous process improvement.

Part II contains the lecture material for the ten sessions. The instructor will find that each of the sessions is structured in a similar manner. First, an overview of the session is given; then, a particular method is described and examples are provided. Instructions on when to use the method and how to construct it follow. Many examples of applications are presented, carefully selected for their usefulness and applicability to the Naval Air Rework Facility workplace. The lecture session ends with a review of the material.

Two additional sessions are included, one on data collection and a final one on quality teams. The data collection unit consists of definitions of data types, the reasons for collecting data, and an explanation of data collection and organization methods. The session on quality teams consists of a description, definition, and review of the purposes of quality teams, as well as discussion of how quality teams document and report their efforts in process improvement. Each page of Part II in the trainer's manual has three parts: (1) a reduced copy of the viewgraph, (2) teaching suggestions, comments, and important points related to the viewgraph content, and (3) space for notes.

Part III contains the material for the laboratory sessions--background information, suggestions on how to conduct the exercises, samples of completed exercises, and blank forms. The laboratory exercises have been selected and developed to lead the student from an understanding of the basic concepts of process analysis and control to practical application.

The course is for all personnel in a total quality management organization, that is, an organization in which process improvement is a continuous activity in all functional areas (e.g., manufacturing, administration) and in which everyone in the organization participates--the chief executive officer as well as the artisan, the managers as well as the technical and support personnel. The problem-solving techniques taught in this course are tools that can help all members of the organization and can be used to improve work processes in all areas.

CONTENTS

INTRODUCTION

Basic Concepts

In a total quality management (TQM) organization, continuous process improvement is sought in all functions of the workplace--in manufacturing, design, engineering, administration, and support. Everyone, from hourly worker to chief executive officer, participates in the process. The result of this effort is a product or service for a customer. Understanding what the process is, recognition of the processes in one's workplace, knowledge of process variation, and the ability to use structured problem-solving techniques are fundamental concerns in the ongoing pursuit of continuous process improvement.

Process

A process can be defined as the combination of people, machines, methods, materials, and environment that work together in a systematic way to arrive at a product or service. Each process is comprised of three elements: (1) input, (2) interaction, and (3) output. As depicted in Figure 1, the input is the resource to be processed. The interaction is the working together of people, machines, methods, materials, and environment on the input, and the output is the product or service.

Input. Examples of inputs, or resources to be processed, are employees to be trained (people), machinery to be repaired (machines), policies to be changed (methods), parts to be machined (materials), and surroundings to be improved (environment).

Interaction. Resources for completing the work can include secretaries, artisans, engineers (people); computers, telephones (machines); chemicals, paper (materials); policies, manuals, memos (methods); and temperature and lighting (environment). Activities in which the resources work together to transform inputs into outputs can include grinding a part, transporting materials, teaching a skill, writing a computer program, requesting information, conducting a meeting, or repairing a faulty air circulation system.

Outputs. Outputs, or products and services produced by the process, can include trained employees, repaired machinery, changed policy, a machined part, or cleaner air.

Example. When you teach this course, the input, or resource to be processed, is the "employee to be trained." The resources to do the processing will be you (the instructor), the manual, the instructional procedure, viewgraphs and viewgraph machine, the classroom facilities and environment (lighting, noise level, temperature), and so forth. All of these resources will interact to convert the input to the output, the "trained employee."

Key Characteristics of Processes

(1) Outputs can be inputs. As can be seen in Figure 2, the output of Process A is the input for Process B, and the output of Process B is the input for Process C. In this example, worker B is a customer of worker A and a supplier to worker C. Thus, each person in an organization has two roles--one as a customer and one as a supplier.

(2) A process can be simple and consist of a few steps, or can be complex and consist of many interrelated steps and subprocesses. A process can be the work of one person in a plating operation, or it can represent the manifold interrelated operations of hundreds of workers whose work results in an overhauled aircraft engine. A flow chart of a complex process, the overhaul of a nose landing gear, is presented in Figure 3. Many

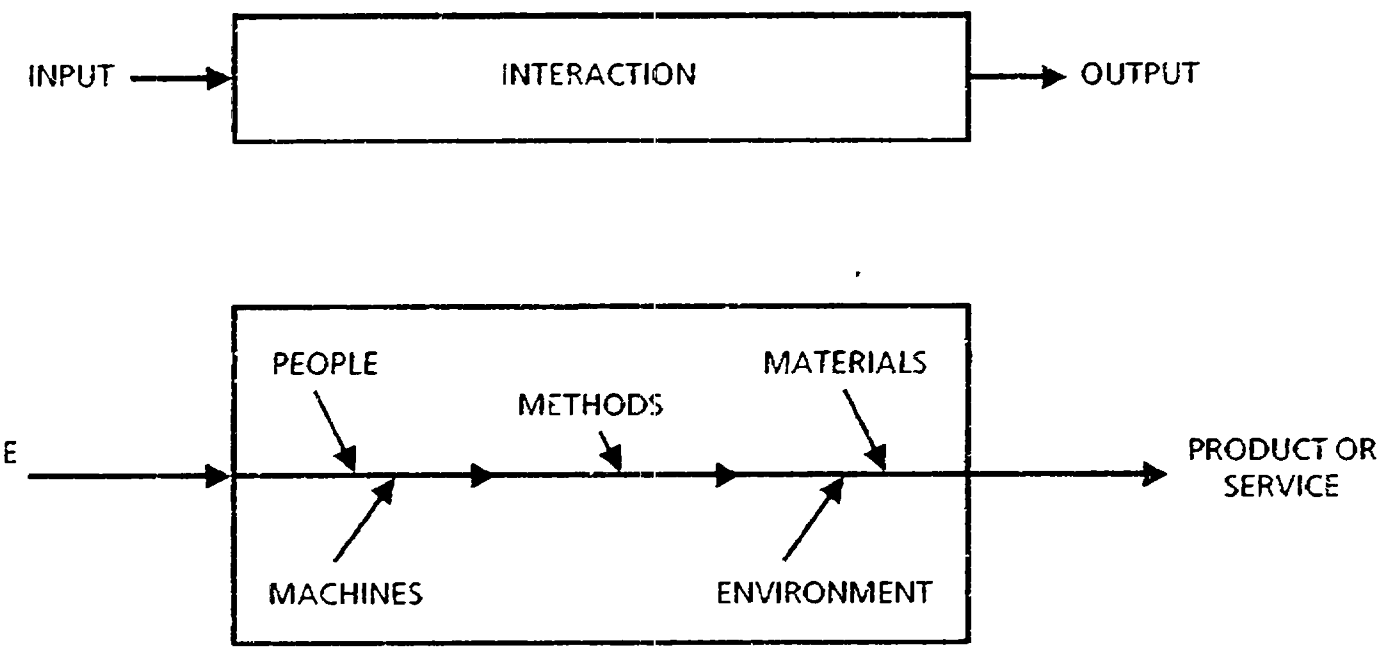


Figure 1. Elements of a process.

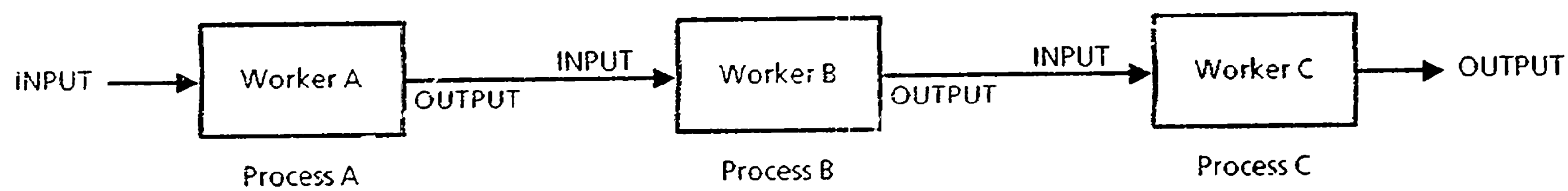
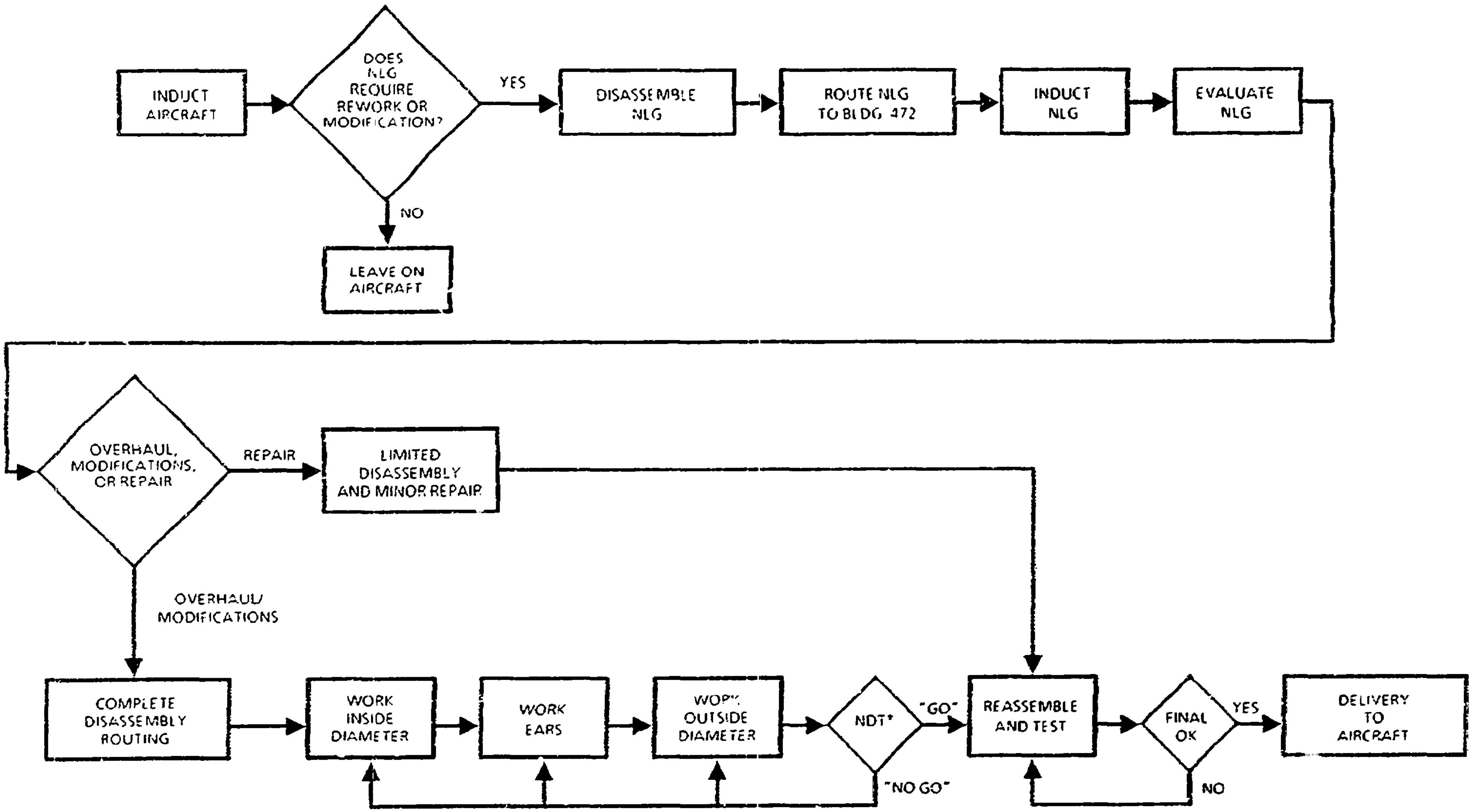


Figure 2. Customer/supplier relationship of processes. Depending on the work process, a worker can function as either a customer or a supplier.



*Nondestructive testing

Figure 3. Nose landing gear (NLG) overhaul process.

people work together using various procedures, equipment, materials, and supplies in differing environs to overhaul the nose landing gear. This major process is comprised of many other processes. One of these, the limited disassembly and minor repair process, is depicted as one box in Figure 3.

(3) <u>The same process can be seen as both simple and complex, depending on how detailed a description is given.</u> The limited disassembly and minor repair process, which is represented as a simple "one box" process in Figure 3, can be depicted as a more complex process. Figure 4 shows the same process in greater detail.

(4) <u>Simple or complex, one type of process is no more or less important than the other.</u> A complex process can be made up of many simpler processes that are interrelated. They may be occurring at the same time or following some special sequence. Regardless, quality builds on quality. The overall quality of a given output is dependent on the quality of all of the processes, simple and complex.

<u>Process Variation</u>

The output of all processes, including those producing output of high quality, will not be exactly the same, hour after hour or day after day. Variation is found in gauge readings, production figures, temperatures, attendance records, completion times, weights, heights, leaves, and snowflakes. Variation is a part of nature.

Variability has many sources. The five resources of people, machines, materials, methods, and environment work together to produce not only output, but fluctuations in output. The fluctuations are caused by differences in the resources, this is, differences in raw materials, equipment, techniques, and so on. Most of the differences are quite small and cause the output to vary in a "normal" way. Sometimes, however, the differences are large--a new employee replaces an experienced employee or material arrives from a different supplier. These differences may make the pattern of output fluctuate in an "abnormal" manner.

Consider your drive to work in the morning. You drive the same car, obey the same traffic laws, follow the same route every day. The trip doesn't take exactly the same time every day. Sometimes it takes more time to get to work, sometimes less. This variation is normal and may be due to the amount of traffic, traffic signals, or weather conditions encountered during the trip. On the other hand, if an out-of-the-ordinary event occurs on your way to work, such as an accident or a flat tire, your trip time may be "abnormally" long.

The typical patterns of traffic, traffic signals, and weather conditions are known as "common causes." Common causes are sources of normal variation that are part of every process. The accident and flat tire are unusual events and are referred to as "special causes" of variation. Special causes are sources of variation that are intermittent, unpredictable, and abnormal.

An understanding of the differences between normal and abnormal variation and of common and special causes is necessary in a TQM organization. Continuous process improvement requires reducing process variation by tracking variation back to its source and taking corrective action so that the output becomes more uniform, predictable, and ultimately more satisfying to the customer.

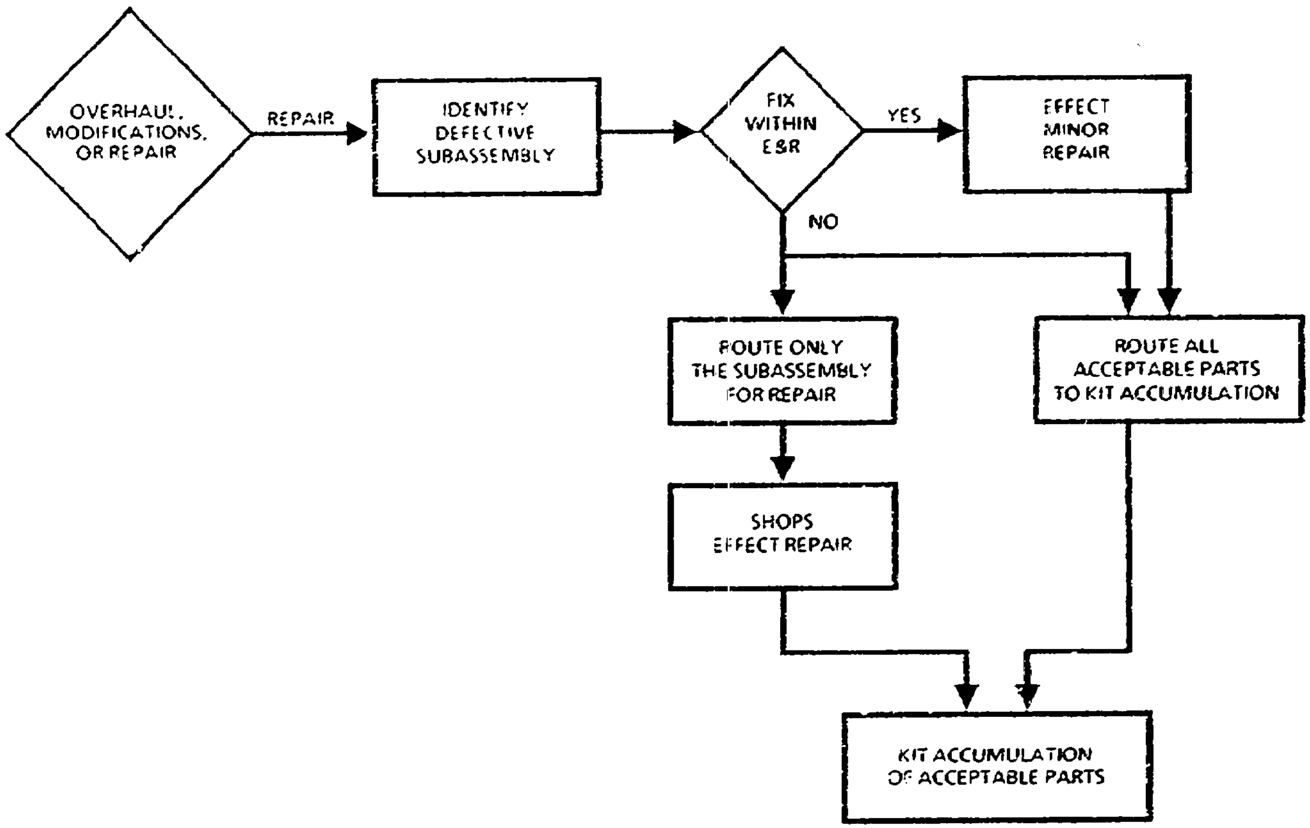


Figure 4. Limited disassembly and minor repair process.

SESSION 1: INTRODUCTION AND OVERVIEW

Continuous Process Improvement

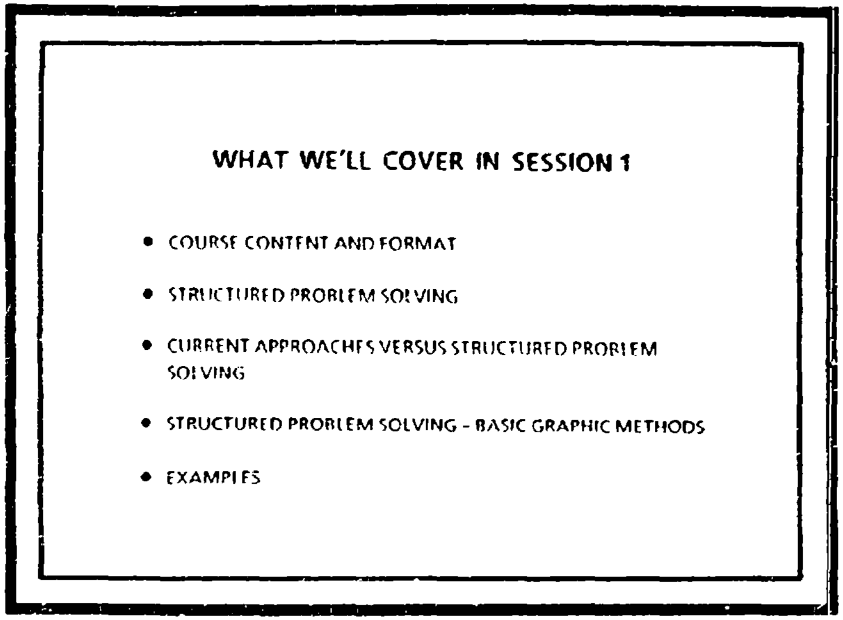
TQM organizations attend to the needs and expectations of the customer and focus on preventing nonacceptable output through continuous process improvement. Within the TQM organization, everyone, from hourly worker to chief executive officer, has a common method of describing and attacking problems, and everyone has a working knowledge of the basic graphic tools necessary for measuring continuous process improvement.

In this course, the PDCA cycle, also called the Shewhart chart or the Deming cycle, is set forth as the foundation for a structured problem-solving approach. Seven basic graphic methods are introduced, utilized, and applied within the PDCA framework. The PDCA activities of examining processes, identifying possible causes of variation, collecting and summarizing data, making recommendations for corrective actions based on the data, and testing and monitoring the effects of the actions taken are carried on and repeated in a never-ending cycle, resulting in a continuous spiral of improvement.

INTRODUCTION AND O' RVIEW

- Introduce the course.
- Introduce yourself and any other trainers to the class.
- Discuss how this training fits in with other training (e.g., Deming philosophy, project team orientation, etc.).
- Emphasize that statistical techniques are just one part of a total quality program.

Instructor's Notes:



- Use this slide to preview Session 1.
- Briefly describe the format of the class and lab.
- Explain the purpose of the notebooks (e.g., they contain copies of the slides to take notes on).
- Encourage the class to stop you to ask questions at anytime.

Instructor's Notes:

WHY WE ARE HERE

- TO HELP YOU BETTER UNDERSTAND YOUR WORK PROCESSES SO THAT YOU CAN IMPROVE AND REFINE THOSE PROCESSES
- TO PROVIDE YOU WITH AN APPROACH TO CONTINUOUSLY IMPROVE THOSE WORK PROCESSES
- TO TEACH YOU TO UNDERSTAND AND USE SPECIFIC METHODS TO CONTROL AND IMPROVE WORK PROCESSES

- **This slide describes some goals for these classes.**
- **Briefly discuss each point.**

Instructor's Notes:

WE ARE NOT HERE

- TO MAKE YOU STATISTICIANS
- TO TEACH YOU COMPLICATED MATHEMATICAL FORMULAS USED TO COMPUTE STATISTICS
- TO CRITICIZE AND FIND FAULT

- Points one and two: While the class will learn some statistics and formulas, they are not expected to become instant experts in these areas.
- Point three: This applies to any suggestions or questions that come up in class.

Instructor's Notes:

COURSE OBJECTIVES

- TO FAMILIARIZE YOU WITH STRUCTURED PROBLEM SOLVING
- TO FAMILIARIZE YOU WITH THE BASIC GRAPHIC METHODS
- TO SHOW YOU WHEN AND HOW TO APPLY THEM
- TO GIVE "HANDS ON" EXPERIENCE WITH THESE BASIC METHODS
- TO SHOW YOU HOW THESE METHODS ARE RELATED TO STRUCTURED PROBLEM SOLVING

- **Reaffirm these training goals.**

Instructor's Notes:

STRUCTURED PROBLEM SOLVING AND THE BASIC GRAPHIC METHODS

Instructors Dr Joyce Shettel Neuber
Dr Sam Landau
Dr Archester Houston

Session	Reading Assignment	Topic
1	none	Introduction, Structured Problem Solving
2	Ch 1	Flow Charts
3	Ch 3	Cause and Effect Diagrams
4	Ch 1 4	Data Collection
5	Ch 5	Pareto Diagrams
6	Ch 2	Histograms
7	Ch 9	Scatter Diagrams
8	Ch 6	Run Charts
9	Ch . 8	Control Charts
10	none	Wrap up

Text Guide to Quality Control by Dr K Ishikawa

Class Format Each session will consist of a lecture and a lab Each lecture and each lab will last approximately 1-1/2 hours In the lecture portion of the class, the purpose, uses and interpretation of the graphic methods will be discussed Work in the lab portion of the class will include learning to construct and apply the graphic methods to job related problems encountered at the NARF Session 10 will include a class discussion of the application of the methods to team projects

- Revise the syllabus to fit your training. Review it for the class.
- Introduce the book and distribute it now.
- Mention that the course and the book are meant to complement one another.
- Recommend to the class that they read related chapters both before and after classes.

Remember:

- Always introduce visitors to the class.

Instructor's Notes:

STRUCTURED PROBLEM SOLVING

FOR

CONTINUOUS IMPROVEMENT

- Discuss why a structured approach to problem solving is needed.
  - People use different approaches to solve problems. Often they use the ones that are best for them as individuals, but not necessarily best for the organization.
  - In group problem solving, the use of many different styles can cause confusion.
  - This approach presents a uniform, systematic method for solving problems so that everyone can use the same procedure.
  - This approach has proved useful in projects aimed at the continuous improvement of quality.

Instructor's Notes:

THE CURRENT APPROACH?

- FIRE FIGHTING
- PUTTING A LOT OF PEOPLE ON A PRESSING PROBLEM
- GOING AROUND THE SYSTEM TO GET THE JOB DONE
- KEEP DOING IT UNTIL YOU GET IT RIGHT
- MAKE THIS QUARTER LOOK GOOD – WORRY ABOUT NEXT QUARTER NEXT QUARTER

- Discuss why these approaches do not contribute to sustained improvement in quality or productivity.
- Ask if class members have experienced them.
- Use a NARF-related example or an example from other companies to illustrate these points.

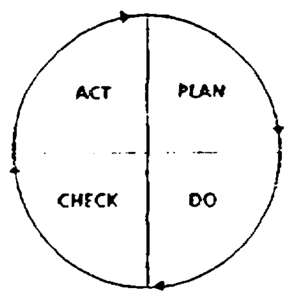
Instructor's Notes:

GROUP APPROACH TO PROBLEM SOLVING

- IDENTIFY MAJOR PROBLEMS
- SELECT ONES TO WORK ON
- LIST ALL POSSIBLE CAUSES
- SELECT THE MOST LIKELY CAUSES FOR STUDY
- COLLECT INFORMATION TO SEE WHETHER THESE ARE CAUSES
- SUGGEST SOLUTIONS
- IMPLEMENT SOLUTIONS
- COLLECT INFORMATION TO SEE IF THE SOLUTIONS HAD AN EFFECT
- REPEAT CYCLE

- This is a non-graphic description of the PDCA cycle.
- Discuss each point.
- Emphasize the role data collection plays both in defining the problem and in assessing the solution.

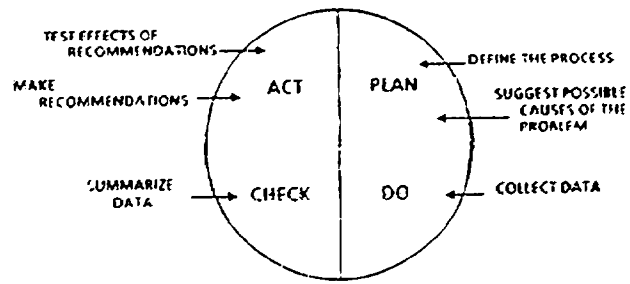
Instructor's Notes:



THE P-D-C-A CYCLE

- First of a three-slide overlay.
- The PDCA cycle originated with Shewhart and was popularized by Deming.
- Myron Tribus was the first to relate the graphic tools to the PDCA cycle.
- NAVPERSRANDCEN expanded upon Dr. Tribus' interpretations by integrating a framework for group problem solving into the PDCA cycle.
- The NAVPERSRANDCEN approach will be the basis for these classes. The PDCA cycle will serve as a framework for learning when and how to use the graphic tools to examine and improve NARF processes.

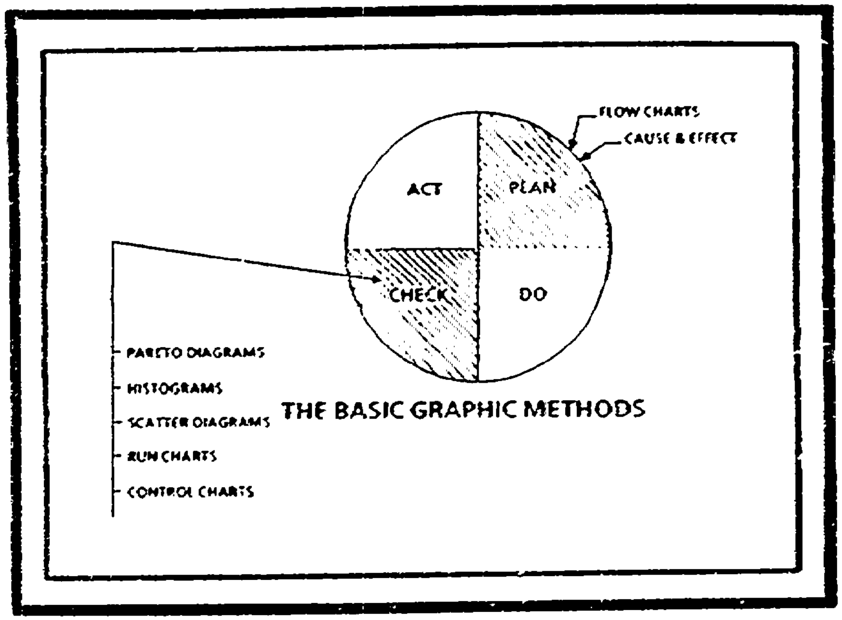
Instructor's Notes:



AND RELATIONSHIP TO
STRUCTURED PROBLEM SOLVING

- Explain the activities within each phase of the PDCA cycle.

Instructor's Notes:



- Explain where the graphic tools are most frequently used. They can be used in other phases too (e.g., Pareto diagrams are *sometimes* used in the Plan phase).
- The PDCA cycle can be used at all levels of a organization. The scope and emphasis of process improvement will vary at different levels.

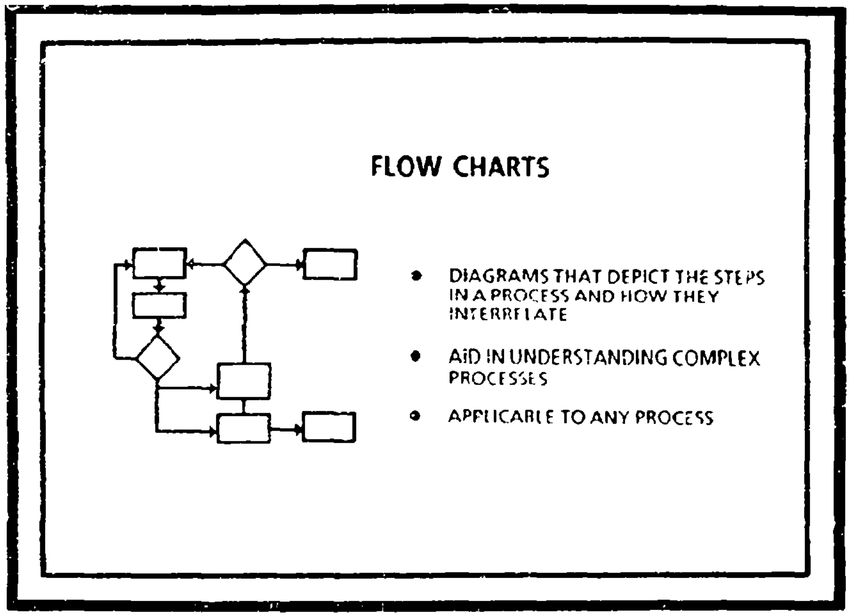
Instructor's Notes:

BASIC GRAPHIC METHODS

- FLOW CHARTS
- CAUSE AND EFFECT DIAGRAMS
- PARETO DIAGRAMS
- HISTOGRAMS
- SCATTER DIAGRAMS
- RUN CHARTS
- CONTROL CHARTS

- Each of these basic graphic methods will be covered in detail in future sessions.
- It is not necessary to use all of these methods during a project. Some teams who have been involved in successful projects have used only one method, and some have not used any.
- A brief summary of each of the methods will follow.

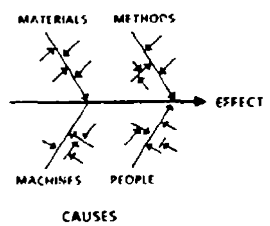
Instructor's Notes:



- Briefly describe the graph and paraphrase the bullets.
- The diamonds are decision boxes and the rectangles are process steps.

Instructor's Notes:

CAUSE-AND-EFFECT DIAGRAMS
(FISHBONE DIAGRAMS)

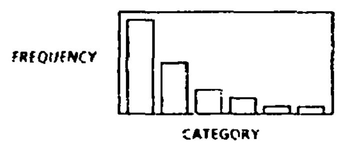


- DIAGRAMS THAT SHOW THE DIFFERENT FACTORS OR CAUSES OF A CERTAIN EFFECT AND HOW THEY INTERRELATE
- AID IN ANALYSIS OF COMPLEX PROBLEMS
- ALLOW ENUMERATION OF POSSIBLE CAUSES OF PROCESS PROBLEMS

- Briefly describe the graph and paraphrase the bullets.
- The name "fishbone diagram" comes from the shape of the graph.
- This graph is also known as an Ishikawa Diagram for Dr. Kaoru Ishikawa, one of Japan's foremost authorities on total quality control, who created it.

Instructor's Notes:

PARETO DIAGRAMS

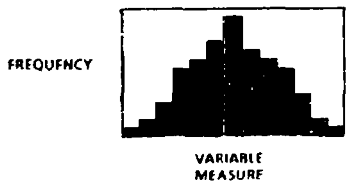


- VERTICAL BAR GRAPHS THAT PLACE CATEGORIES IN DECREASING ORDER OF FREQUENCY FROM LEFT TO RIGHT
- USEFUL FOR PROBLEM ANALYSIS
- FOCUS ATTENTION ON PROBLEMS IN PRIORITY ORDER
- HELPFUL FOR COMPARING DATA CHANGES DURING DIFFERENT TIME PERIODS

- Briefly describe the graph and paraphrase the bullets.
- Pareto diagrams help to prioritize problems.

Instructor's Notes:

HISTOGRAMS

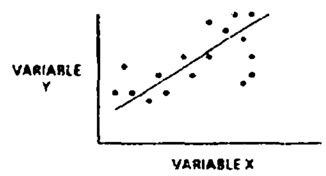


- VERTICAL BAR GRAPHS THAT DEPICT THE DISTRIBUTION OF A SET OF CONTINUOUS DATA
- SUMMARIZE DATA CONCISELY AND EFFECTIVELY
- USEFUL COMMUNICATION TOOL
- FACILITATE IDENTIFICATION OF CAUSES OF VARIATION

- Briefly describe the graph and paraphrase the bullets.
- Histograms are especially helpful in summarizing large amounts of information.

Instructor's Notes:

SCATTER DIAGRAMS

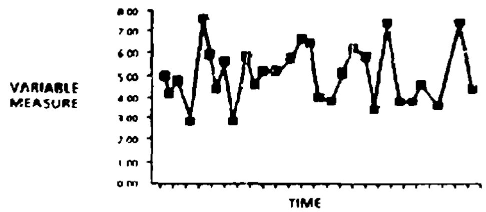


- DIAGRAMS THAT SHOW THE RELATIONSHIP BETWEEN TWO VARIABLES
- FACILITATE STUDYING POSSIBLE RELATIONSHIPS BETWEEN VARIABLES
- USEFUL IN FINDING A CAUSE FOR PROCESS PROBLEMS

- Briefly describe the graph and paraphrase the bullets.
- Scatter diagrams are a simple way of looking at the relationship between two variables.
- To illustrate a scatter diagram, graph the relationship between height and weight.

Instructor's Notes:

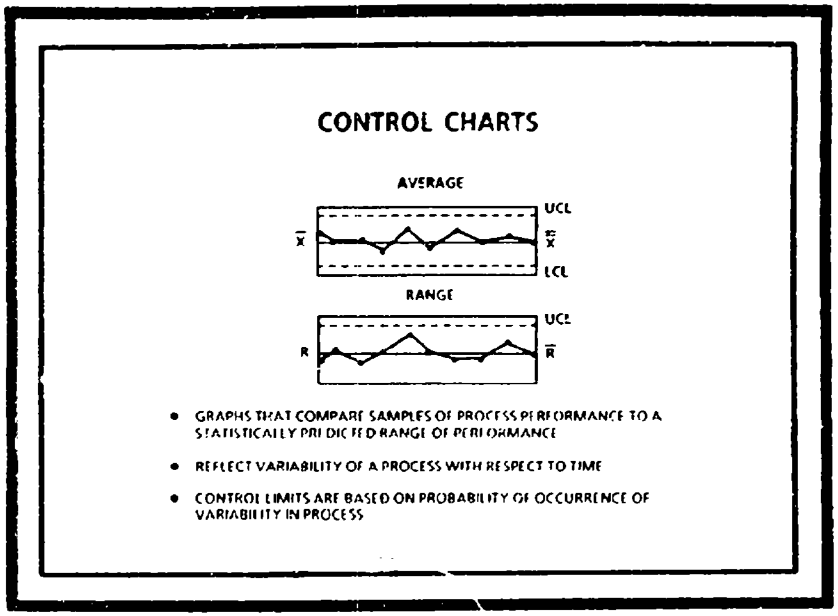
RUN CHARTS



- LINE GRAPHS THAT SHOW DATA PLOTTED OVER TIME
- SIMPLE TO CONSTRUCT
- USEFUL IN UNDERSTANDING BASIC CHARACTERISTICS OF A PROCESS
- CAN CONTAIN SPECIFICATION LIMITS TO DEMONSTRATE HOW PRODUCT RELATES TO THEM

- Briefly describe the graph and paraphrase the bullets.
- Run charts are often used to examine how a variable changes over time.
- To illustrate a run chart, graph temperatures for a month.

Instructor's Notes:



- Briefly describe the graphs and paraphrase the bullets.
- A control chart is a graph that compares samples of process performances to a statistically predicted range of performance.
- Control charts are a more advanced graphic method, and our coverage of them will serve only as an introduction.
- Some people think control charts ARE Statistical Quality Control (SQC), when in fact many process improvements can be made using only the more simple graphic methods.

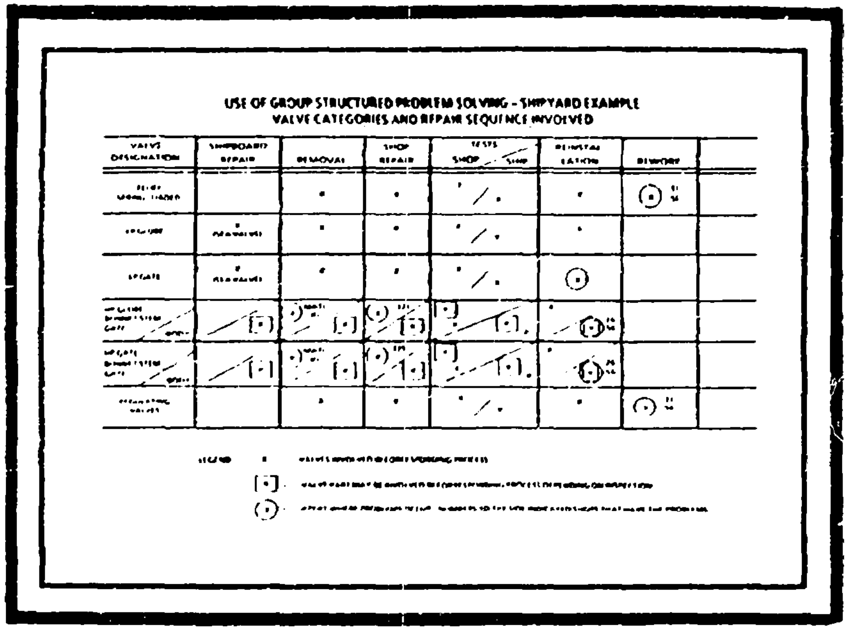
Instructor's Notes:

The next seven slides concern a problem-solving project at Long Beach Naval Shipyard (LBNS).

The next three slides illustrate the Plan phase of the PDCA cycle.

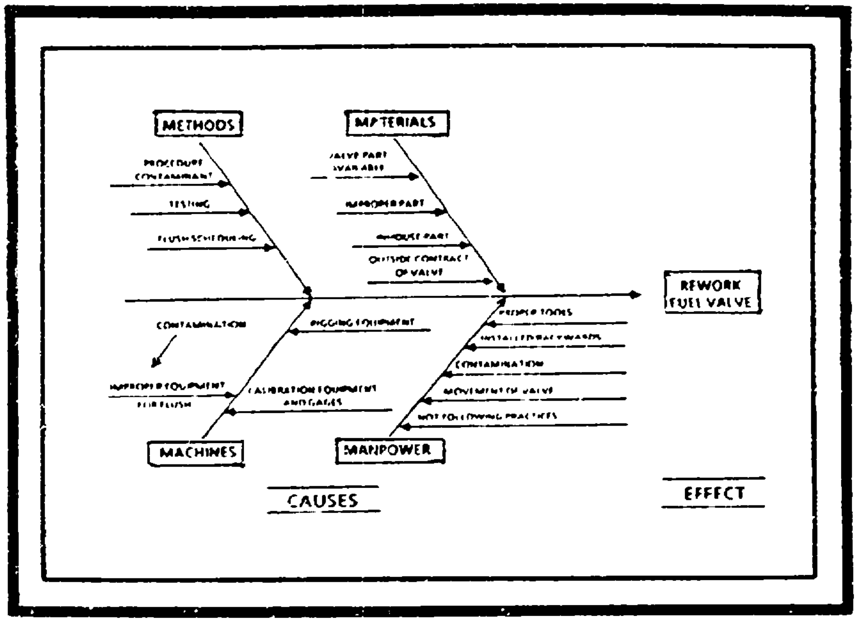
Many valves repaired at LBNS were failing after being reinstalled on the ships. The blame for the valve failures was being placed on the valve shop. Because of the great cost incurred by resultant ship delays and additional manhours, a special project team was assembled to study the problem and pinpoint its causes.

The project team was made up of first-line supervisors from the several departments involved in the removal, repair, and installation of the valves.



- The purpose of this slide is to show how the project team described the process, so don't spend a lot of time on details of the matrix.
- The chart lists types of valves LBNS repairs (vertical axis) and the stages in the repair process (horizontal axis).
- Problems with the valves at different stages of the repair process are noted along with the related shop number. Additional information is described by the legend.

Instructor's Notes:



- Review the parts of the diagram.
- The purpose of this slide is to show how the project team used the cause-and-effect diagram to better understand the problems associated with fuel valves.
- It helped them to narrow the focus of their investigation.
- To simplify the project, the team chose to focus on one valve.
- The team chose the Leslie fuel oil valve because:
  - It is critical to ship performance.
  - It is a common valve on ships.
  - There were many problems reported with this type of valve.
- The project team decided to begin by investigating sources of valve contamination because it was cited under three of the four major causes in the cause-and-effect diagram.

Instructor's Notes:

THEORIES OF CAUSE OF CONTAMINATION

IMPROPER SYSTEM BLANKING
- LACK OF KNOWLEDGE OF EM&S STANDARD 0630 6010
- NEED OF TRAINING IN PROPER PROCEDURES
- LACK OF SUPERVISORY ENFORCEMENT

SYSTEM FLUSHING PROCEDURES
- PARTIAL SYSTEM FLUSH VS ENTIRE SYSTEM
- INSUFFICIENT CAPACITY OF FLUSHING PUMPS
- NEED FOR A STANDARD/PROCESS INSTRUCTION ON FLUSHING
- EFFECT OF COMPOSITION OF PIPE (STEEL VS CUNI)
- CLEANLINESS OF NEW FUEL

SHOP CLEANING (PICKLING) INSUFFICIENT

- The project team generated this list of possible causes of contamination.

Blanking refers to covering the ends of pipes when a valve is removed from that pipe.

Flushing refers to pumping a cleaning solution through the on-board fuel line system.

Instructor's Notes:

- These next four slides show how the LBNS project team used the PDCA cycle to test two ways that contamination could cause fuel valve failure.
- The first project involved the study of how the flushing system affected the contamination of valves.

STRUCTURED PROBLEM SOLVING – EXAMPLE 1

PLAN

- CONTAMINATION IS CAUSED BY AN INADEQUATE FLUSHING SYSTEM

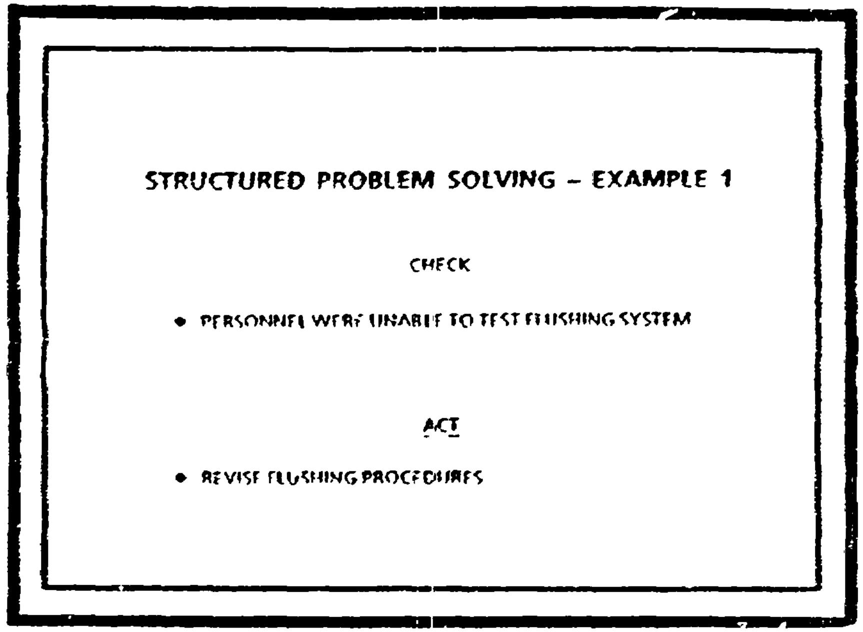
DO

- EXAMINE STATUS OF FLUSHING SYSTEMS

- In the Do phase of the PDCA cycle the project team surveyed personnel working with the flushing system.
- The project team also asked recently trained personnel about the flushing methods.

Instructor's Notes:

- Note the simple methods used to complete this PDCA cycle (e g , cause-and-effect diagrams and interview)



- In the Check phase the team determined that workers could not tell if the system was thoroughly flushed.
- In the Act phase the team suggested:
  - The flushing procedures be revised so personnel could know if the system was completely flushed.
  - Workers be issued the appropriate tools and equipment.
- These proposals were forwarded to a higher management level for further action.

Instructor's Notes:

STRUCTURED PROBLEM SOLVING – EXAMPLE 2

PLAN

- CONTAMINATION IS CAUSED BY IMPROPER SYSTEM BLANKING

DO

- POLL WORKERS ON PROPER METHODS
- SURVEY BLANKING PROCEDURES
- REVIEW STANDARD 0630 6010

- The second project examined the relationship between blanking of pipes and contamination.
- During the Do phase the team:
  - Polled recently trained workers on proper blanking methods.
  - Did an on-ship spot check, sampling some pipes that were blanked.
  - Reviewed blanking method documentation.

Instructor's Notes:

In the Check phase the team found:

- Workers, including those trained recently, had poor knowledge of blanking methods.
- Four out of seven pipes sampled were improperly blanked.
- The documentation on blanking methods was hard to get to and hard to understand.

In the Act phase the team recommended:

- A short film on blanking methods be included in formal training.
- A "quality cue card" with simple blanking instructions be carried by workers.
- A revision of official blanking standards.

STRUCTURED PROBLEM SOLVING – EXAMPLE 2

CHECK

- WORKER KNOWLEDGE OF BLANKING METHODS POOR
- MANY INSTANCES OF IMPROPER METHODS
- STANDARDS PROVED TOO COMPLICATED

ACT

- PRODUCE SHORT FILM ABOUT BLANKING METHODS
- PRODUCE 'QUALITY CUE CARD'
- REVISE STANDARD 0630 6010

- Remind the class of the simple methods used during this project.
- Originally, the valve repair shop was being blamed for the problem with valves failing.
- Through the use of the PDCA cycle the project team found several other areas, unrelated to the valve repair shop, that could be responsible for valve failure.
- Further verification of these theories would include a comparison of valve failure rates before and after implementation of project team recommendations.

Instructor's Notes:

SUMMARY OF INTRODUCTION AND OVERVIEW

- COURSE CONTENT AND FORMAT
- STRUCTURED PROBLEM SOLVING
- CURRENT APPROACHES VERSUS STRUCTURED PROBLEM SOLVING
- STRUCTURED PROBLEM SOLVING – BASIC GRAPHIC METHODS
- EXAMPLES

- Use this slide to review the major points of Session 1.
- At this point you may wish to preview the Session 1 lab exercise.

Instructor's Notes:

SESSION 2: FLOW CHARTS

FLOW CHARTS

- Review the Session 1 lab exercise.
- Introduce Session 2.

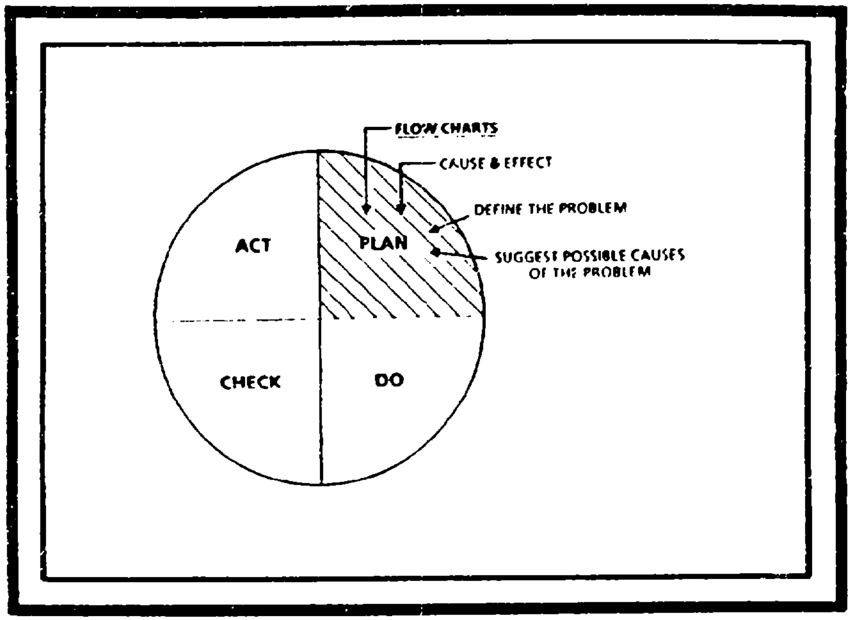
Instructor's Notes:

WHAT WE'LL COVER IN SESSION 2

- ADVANTAGES TO USING THE BASIC GRAPHIC METHODS
- FLOW CHARTS
  - DEFINITION
  - USES
  - CONSTRUCTION
  - EXAMPLES

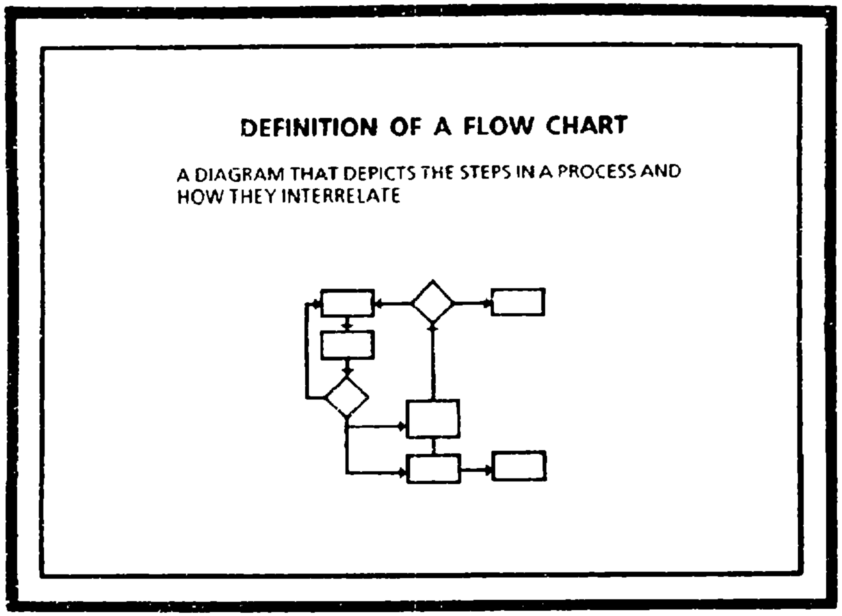
- Use this slide to preview Session 2.

Instructor's Notes:



- Review the PDCA cycle.
- Flow charts are most often used in the Plan phase of the PDCA cycle.
- Flow charts help you to better understand a process.

Instructor's Notes:



- The next topic in this session is flow charts. Use this slide to briefly review the form and definition of a flow chart.

Instructor's Notes:

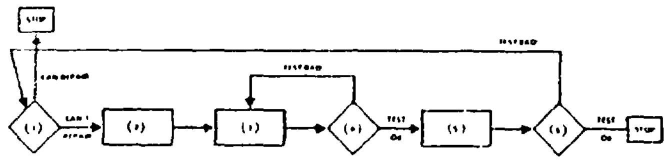
STEPS IN THE REMOVAL AND REPAIR OF A VALVE

1. SHIPBOARD REPAIR
2. REMOVAL OF VALVE
3. SHOP REPAIR
4. SHOP TESTS OF VALVE
5. REINSTALLATION OF VALVE
6. SHIPBOARD TEST
7. REWORK NECESSARY?

- The Long Beach Naval Shipyard valve project discussed in Session 1 can be used to illustrate flow charts.
- Briefly review the steps in the removal and repair of a valve.

Instructor's Notes:

STEPS IN THE REMOVAL AND REPAIR OF A VALVE



① SHIPBOARD REPAIR

② REMOVAL OF VALVE

③ SHOP REPAIR

④ SHOP TESTS OF VALVE

⑤ REINSTALLATION OF VALVE

⑥ SHIPBOARD TEST

- Here are the steps in the repair of a valve represented in a flow chart.
- Point out the decision diamonds and the process step boxes.
- Describe the process flow, step by step, including the loops to previous steps.
- The steps are listed below because the words would not fit in the boxes.

Instructor's Notes:

STEPS IN CONSTRUCTING A FLOW CHART

1. BEGIN BY WRITING DOWN, IN ORDER, THE MAJOR STEPS IN THE SYSTEM YOU ARE CHARTING
2. WRITE THE STEPS IN ORDER ON A PIECE OF PAPER. THE ORDER USUALLY GOES FROM LEFT TO RIGHT, BUT ALSO CAN PROGRESS FROM TOP TO BOTTOM
3. BOX ALL OF THE STEPS. A DIAMOND BOX REPRESENTS A DECISION POINT, A RECTANGULAR BOX A STEP IN THE SYSTEM
4. CONNECT THE BOXED STEPS WITH ARROWS TO SHOW THEIR ORDER. SOMETIMES THE FLOW SPLITS AND HAS MORE THAN ONE POSSIBLE SEQUENCE
5. LABEL THE FLOW CHART WITH A DESCRIPTION OF THE SYSTEM IT SHOWS. DISCUSS IT. CHOOSE AN AREA TO DETAIL FURTHER AND START AGAIN.

- Briefly review these steps.
- Using a blackboard, draw the symbols as necessary.

Instructor's Notes:

WHEN A FLOW CHART IS USED

- TO UNDERSTAND A SYSTEM
- TO LOOK FOR "WEAK LINKS" OR INEFFICIENCIES IN A SYSTEM
- TO REACH AGREEMENT AS TO HOW A SYSTEM WORKS
- TO IDENTIFY DIFFERENCES IN THE FORMAL SYSTEM AND THE INFORMAL SYSTEM
- TO SHOW THE IDEAL SYSTEM

- Briefly review these points.

Instructor's Notes:

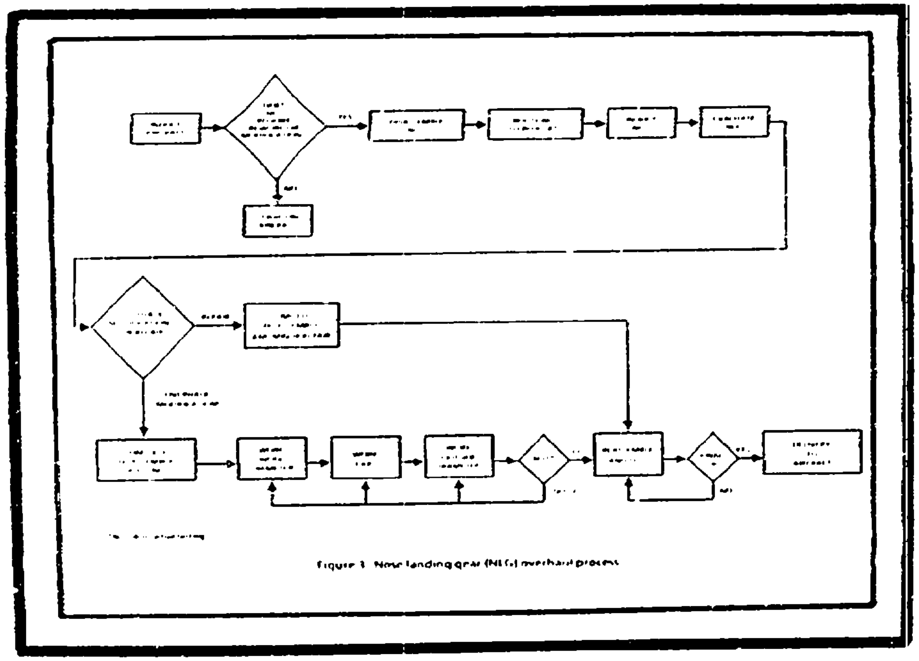
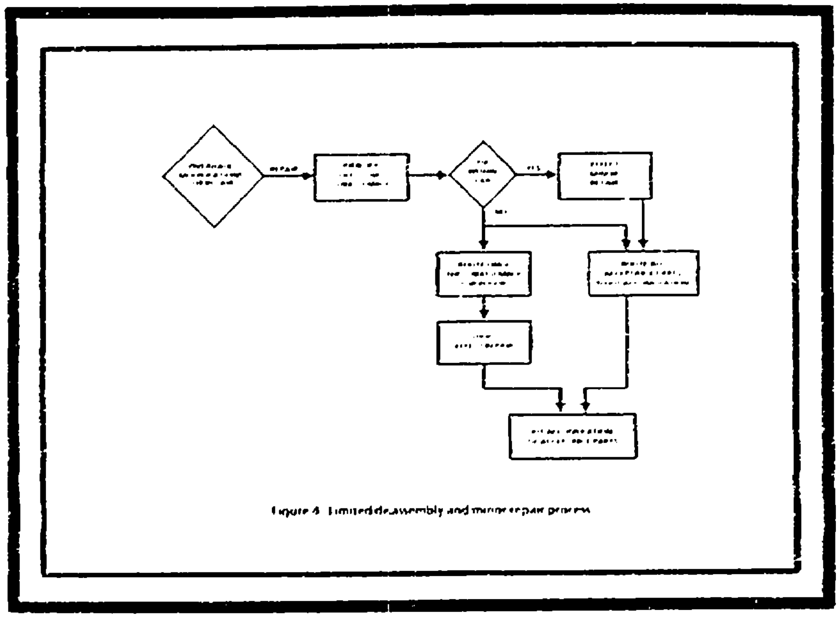


Figure 3. Nose landing gear (NLG) overhaul process

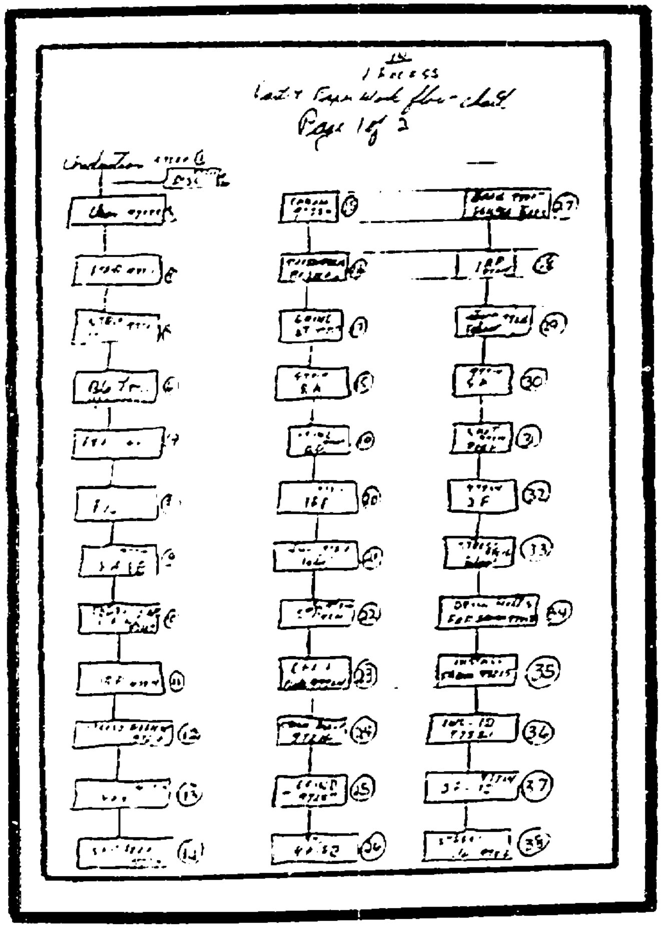
- Describe the steps in this NARF process flow chart.
- You may wish to substitute an example that applies to the group you are training.

Instructor's Notes:



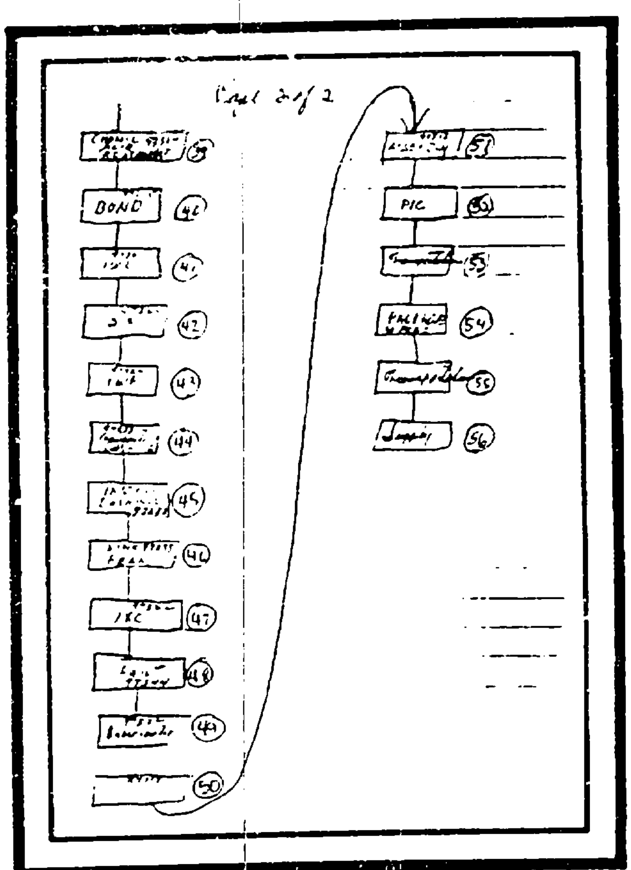
- This flow chart details the "limited disassembly and minor repair" process in the previous flow chart.
- This and the previous slide show that a flow chart can be used to:
  - Briefly summarize the major steps in a process.
  - Describe any number of these steps in detail.
- *Often, the most valuable information gained* from flowcharting a process comes from what you learn about that process during the graphing session.

Instructor's Notes:



- These next two slides are of a flow chart made by a member of a NARF project team.
- It is a flow chart of the points in a process when a part and its paperwork are separated (56 times!).

Instructor's Notes:



- While the form of the flow chart was not perfect (the arrows are missing) it provided a learning experience for the person who made it.
- By flowcharting this process, the person realized the process itself made it more likely that paperwork and parts would be mismatched or separated.

Instructor's Notes:

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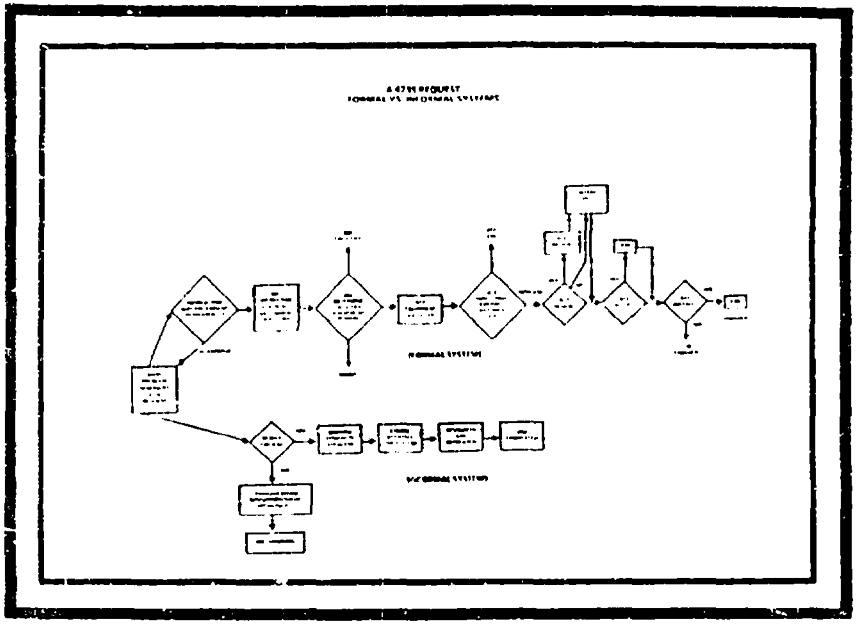
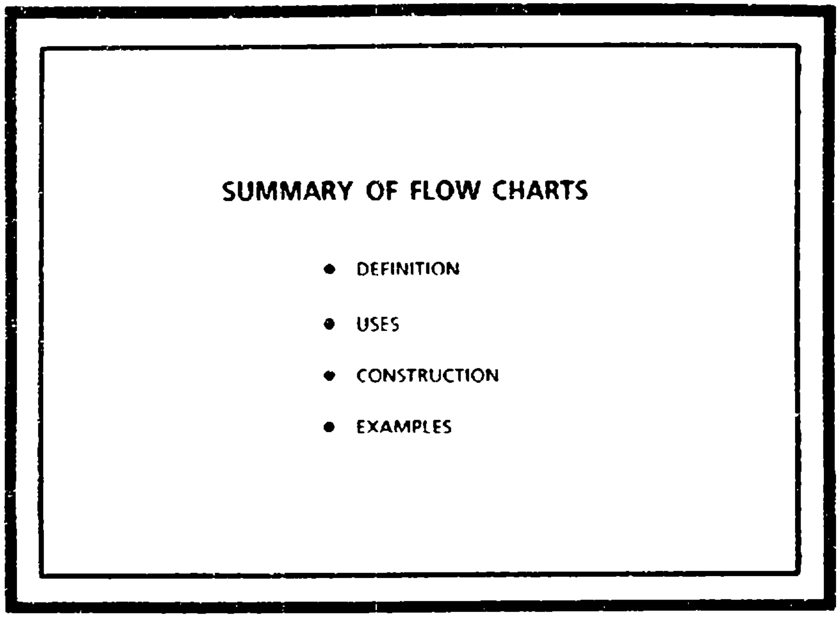


- This flow chart compares a formal and informal system at the NARF. You may wish to substitute an example specific to the group *you are training*.
- Discuss problems that may be encountered when formal and informal systems are different.
  - Time-related problems (e.g., time wasted while hunting down a part in the informal lost and found).
  - Standards suffer (e.g., when a worker may use expedient, but inappropriate methods).

Instructor's Notes:



- Use this slide to review the major points of Session 2.

Instructor's Notes:

SESSION 3: CAUSE-AND-EFFECT DIAGRAMS

CAUSE-AND-EFFECT DIAGRAMS

- Review the Session 2 lab exercise.
- Introduce Session 3.

Instructor's Notes:

WHAT WE'LL COVER IN SESSION 3

CAUSE-AND-EFFECT DIAGRAMS

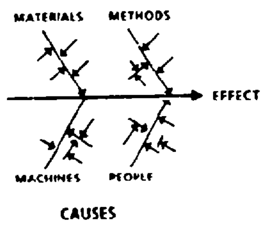
- DEFINITION
- USES
- CONSTRUCTION
- EXAMPLES

- Use this slide to preview Session 3.

Instructor's Notes:

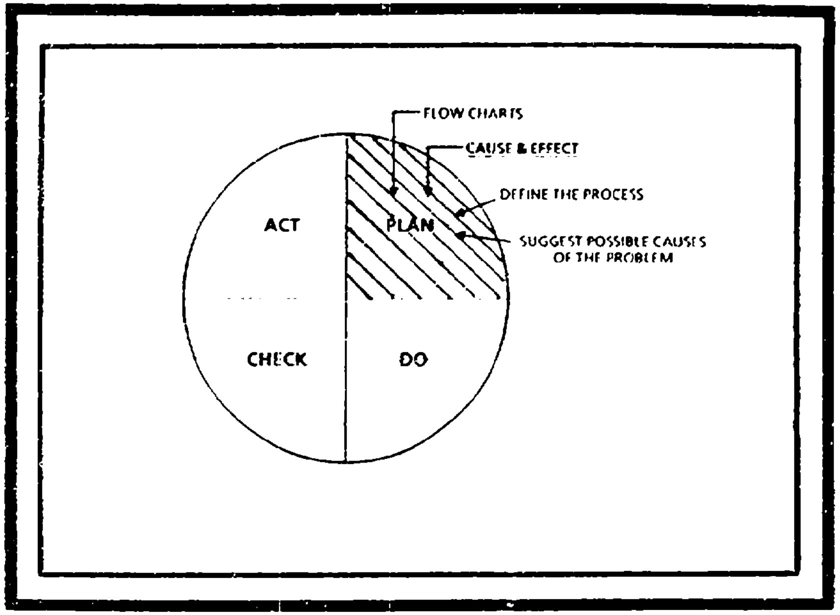
DEFINITION OF A CAUSE-AND-EFFECT DIAGRAM

A DIAGRAM THAT SHOWS THE DIFFERENT FACTORS OR CAUSES OF A CERTAIN EFFECT AND HOW THEY INTERRELATE



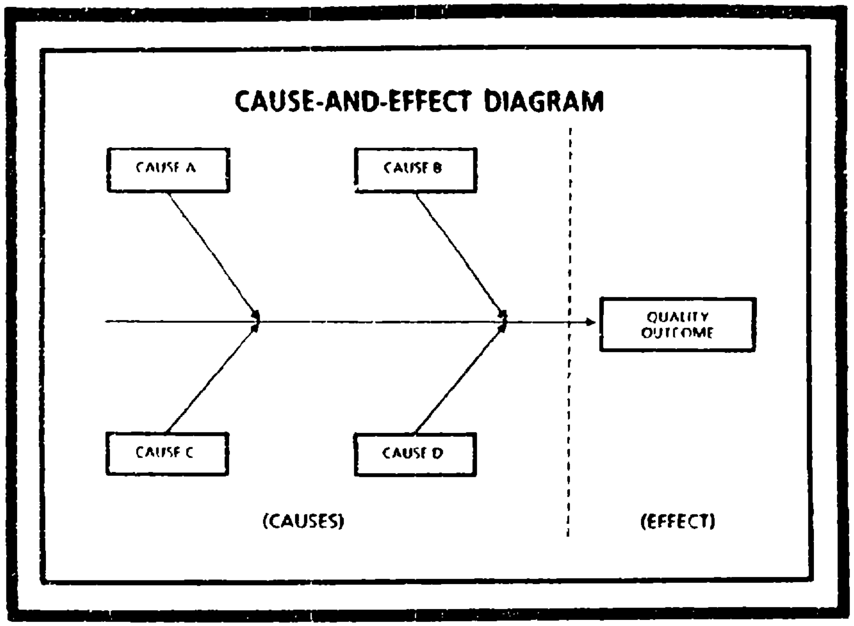
- Use this slide to briefly review the form and definition of a cause-and-effect diagram.

Instructor's Notes:



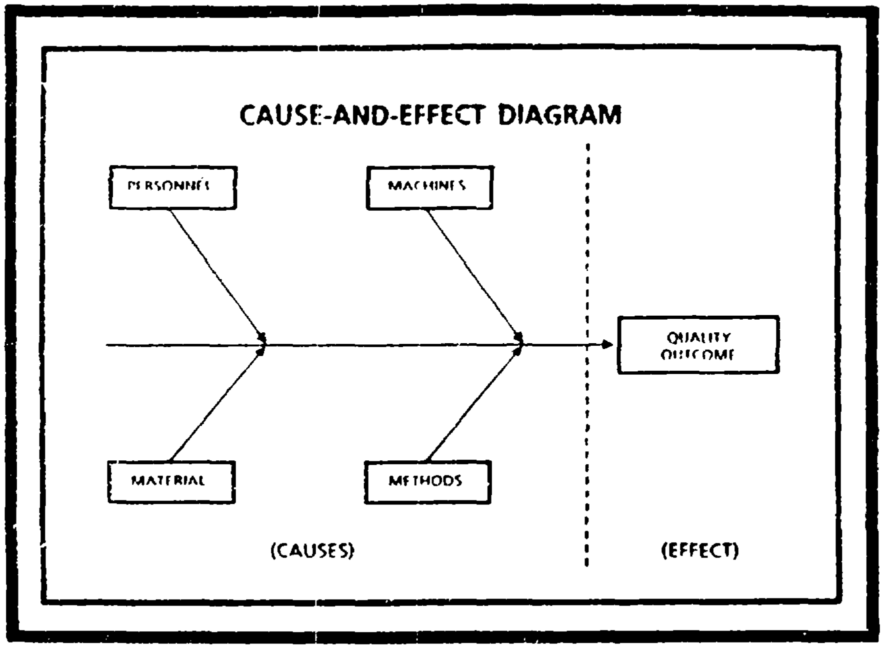
- Review the PDCA cycle.
- Cause-and-effect diagrams are most frequently used in the Plan phase of the PDCA cycle.
- Cause-and-effect diagrams can help you better understand what causes a good system to work or a poor system to fail.

Instructor's Notes:



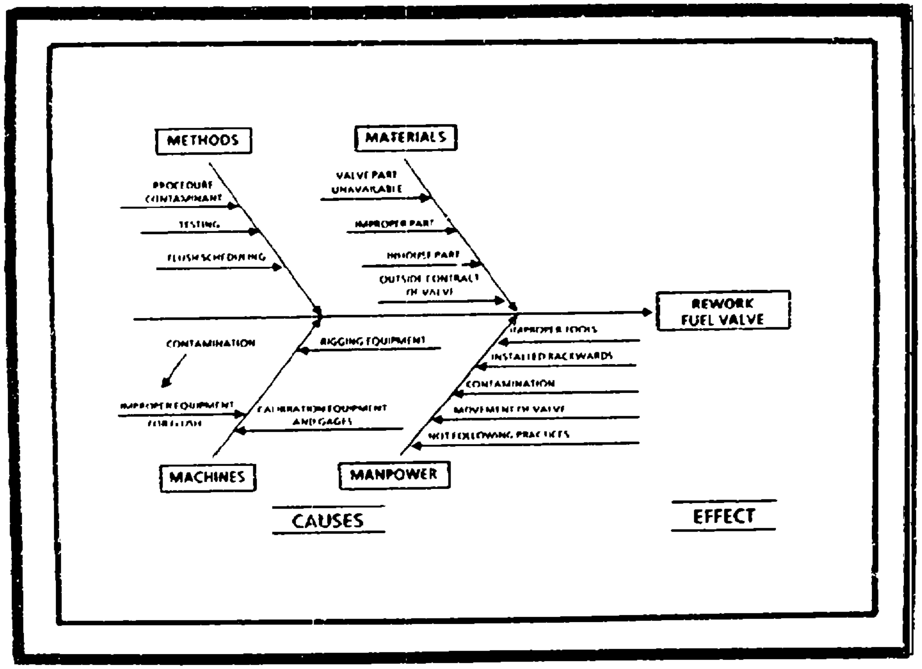
- This slide shows the general structure of a cause-and-effect diagram.
- To the right of the dotted line is the quality outcome. This is the problem or process (good or bad) you are trying to describe.
- To the left of the dotted line are the causes or influences on the quality outcome.

Instructor's Notes:



- Ishikawa suggests these four major categories, called the 4 Ms (Personnel is a substitute for manpower).
- Remind the class members that they are not limited to these 4 categories.
- Examples of other categories are cost and environment.

Instructor's Notes:



- This is the cause-and-effect diagram from the Long Beach Naval Shipyard example discussed in Session 1.
- Briefly review the diagram.

Instructor's Notes:

STEPS IN CONSTRUCTING A CAUSE-AND-EFFECT DIAGRAM

1. DRAW A HORIZONTAL ARROW POINTING RIGHT. THIS ARROW REPRESENTS THE PROCESS TO BE DIAGRAMMED.
2. TO THE RIGHT OF THE MAIN ARROW, WRITE A BRIEF DESCRIPTION OF THE EFFECT OR QUALITY OUTCOME WHICH RESULTS FROM THE PROCESS. DRAW A BOX AROUND THOSE WORDS.
3. WRITE THE MAJOR CAUSES OR FACTORS (E.G., THE 4 M'S) IN BOXES PLACED PARALLEL TO AND SOME DISTANCE FROM THE MAIN ARROW. CONNECT THE BOXES WITH ARROWS WHICH SLANT TOWARD AND TOUCH THE MAIN ARROW.
4. WRITE THE MINOR CAUSES ON THE CHART, CLUSTERED AROUND THE MAJOR CAUSE WHICH THEY INFLUENCE. CONNECT THEM WITH ARROWS POINTING TOWARD THE MAJOR-CAUSE ARROW.
5. DIVIDE AND SUB-DIVIDE THE CAUSES, AS ACCURATELY AS POSSIBLE, TO SHOW HOW THEY INTERACT.

- Use a blackboard to draw examples as you discuss these steps with the class.
- Draw the basic fishbone structure for the example to be covered in the lab session.

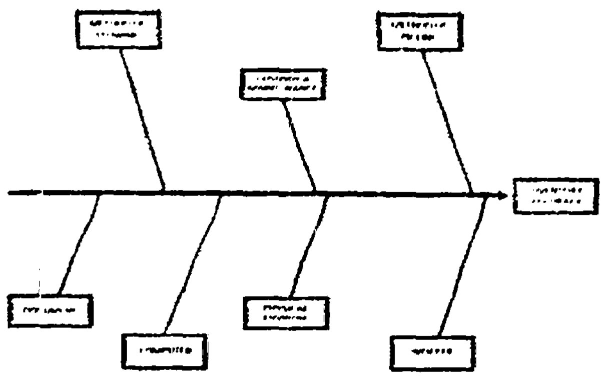
Instructor's Notes:

WHEN A CAUSE-AND-EFFECT DIAGRAM IS USED

- TO PUT CAUSE-AND EFFECT RELATIONSHIPS IN AN ORDERLY, EASILY READ FORMAT
- TO ANALYZE EXISTING PROBLEMS SO THAT CORRECTIVE ACTION CAN BE TAKEN
- TO STUDY A GOOD EFFECT AND UNDERSTAND THE SYSTEM THAT PRODUCES IT
- TO SORT OUT "TRUE" CAUSES FROM THOSE THAT DON'T CONTRIBUTE TO THE EFFECT

- Cause-and-effect diagrams can be used as a road map for problem solving.
- Notations can be made on the diagram to document the results of data collection.

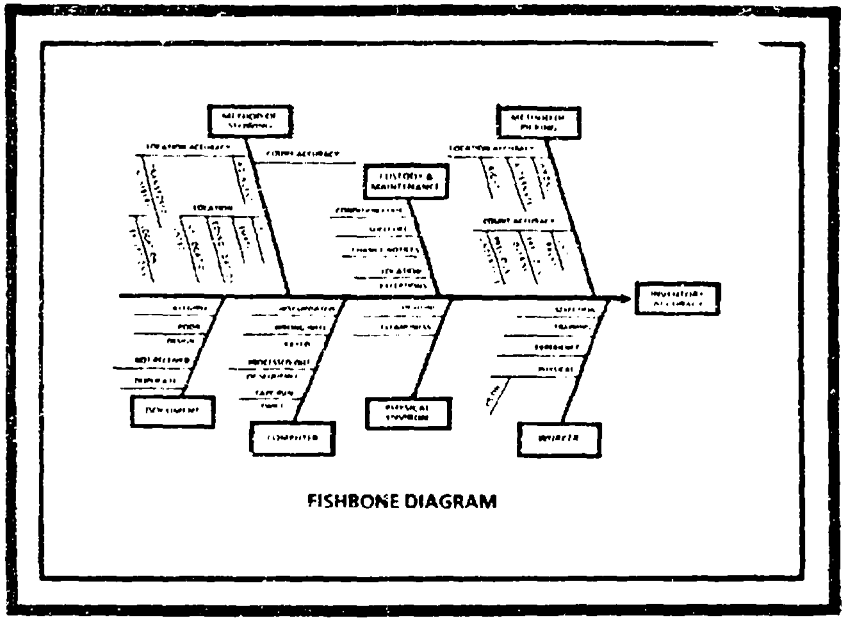
Instructor's Notes:



FISHBONE DIAGRAM

- The next two cause-and-effect diagrams were developed for the Naval Supply Center by a project team from NAVPERSRANDCEN.
- The diagrams depict the causes related to inventory accuracy.
- This slide shows the general categories thought to affect inventory accuracy.
- The three causes on the upper side of the diagram are major stages in material storage and handling.

Instructor's Notes:



- This slide shows the finished cause-and-effect diagram.
- This detailed cause-and-effect diagram can provide a framework for problem solving and suggestions for projects.
- Work through some of the diagram with the class.

Instructor's Notes:

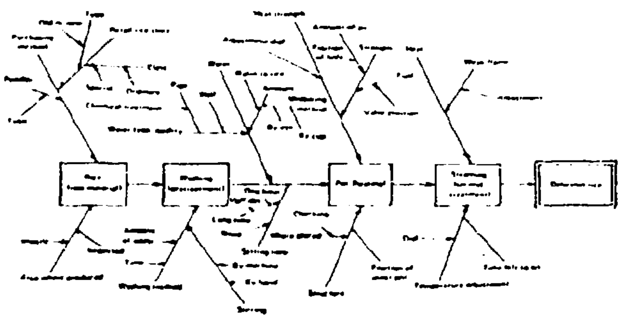
THREE TYPES OF CAUSE-AND-EFFECT DIAGRAMS

- CAUSE ENUMERATION
- DISPERSION ANALYSIS
- PROCESS ANALYSIS

- These three types of cause-and-effect diagrams are discussed by Ishikawa.
- Give a brief example of each type of cause-and-effect diagram. Use previous examples where they apply.
- Direct the class to pages 3-14 and 3-15 of their notebooks for a summary of the different types of cause-and-effect diagrams.

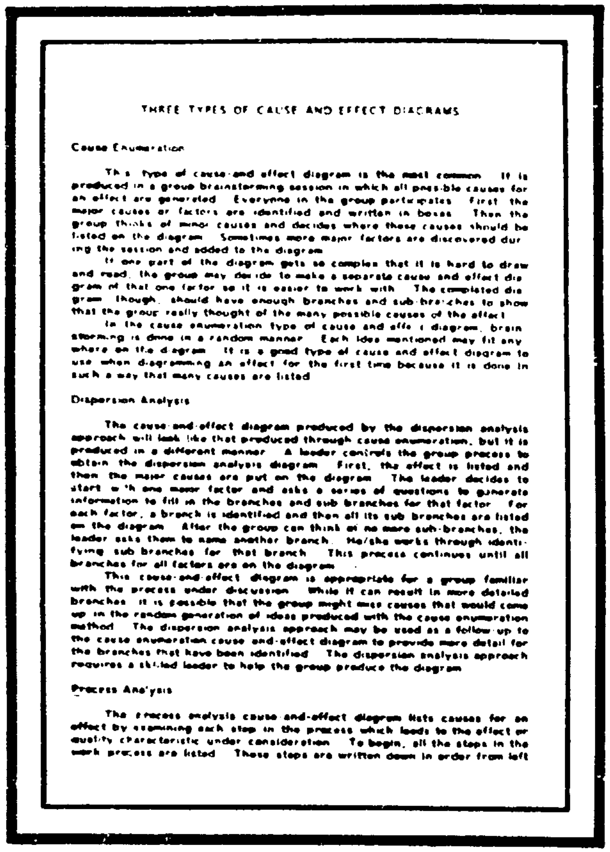
Instructor's Notes:

CAUSE-AND-EFFECT DIAGRAM
PROCESS CLASSIFICATION TYPE



- Briefly describe this example of a process classification cause-and-effect diagram. The example came from Ishikawa, p. 154.

Instructor's Notes:



THREE TYPES OF CAUSE AND EFFECT DIAGRAMS

Cause Enumeration

This type of cause-and-effect diagram is the most common. It is produced in a group brainstorming session in which all possible causes for an effect are generated. Everyone in the group participates. First the major causes or factors are identified and written in boxes. Then the group thinks of minor causes and decides where these causes should be listed on the diagram. Sometimes more major factors are discovered during the session and added to the diagram.

If one part of the diagram gets so complex that it is hard to draw and read, the group may decide to make a separate cause and effect diagram of that one factor so it is easier to work with. The completed diagram, though, should have enough branches and sub-branches to show that the group really thought of the many possible causes of the effect.

In the cause enumeration type of cause and effect diagram, brainstorming is done in a random manner. Each idea mentioned may fit anywhere on the diagram. It is a good type of cause and effect diagram to use when diagramming an effect for the first time because it is done in such a way that many causes are listed.

Dispersion Analysis

The cause-and-effect diagram produced by the dispersion analysis approach will look like that produced through cause enumeration, but it is produced in a different manner. A leader controls the group process to obtain the dispersion analysis diagram. First, the effect is listed and then the major causes are put on the diagram. The leader decides to start with one major factor and asks a series of questions to generate information to fill in the branches and sub branches for that factor. For each factor, a branch is identified and then all its sub branches are listed on the diagram. After the group can think of no more sub-branches, the leader asks them to name another branch. He/she works through identifying sub branches for that branch. This process continues until all branches for all factors are on the diagram.

This cause-and-effect diagram is appropriate for a group familiar with the process under discussion. While it can result in more detailed branches, it is possible that the group might miss causes that would come up in the random generation of ideas produced with the cause enumeration method. The dispersion analysis approach may be used as a follow-up to the cause enumeration cause-and-effect diagram to provide more detail for the branches that have been identified. The dispersion analysis approach requires a skilled leader to help the group produce the diagram.

Process Analysis

The process analysis cause-and-effect diagram lists causes for an effect by examining each step in the process which leads to the effect or quality characteristic under consideration. To begin, all the steps in the work process are listed. These steps are written down in order from left

- The next two slides summarize the three types of cause-and-effect diagrams.
- If you already directed the class to read them, you may omit them from your presentation.

Instructor's Notes:

to right, enclosed in boxes, and connected by arrows pointing right. The last arrow points to the quality characteristic.

The group begins to name causes for the quality characteristic. The group may choose to consider each process step separately or to generate ideas about the whole process. Whichever way it is done, the causes are joined to the step in the process to which they are related.

This diagram provides a good representation of how causes relate to steps in the process. It can become messy and hard to read if many causes are repeated for each step in the process. The group also needs to be careful to think of causes which may occur before or after major steps in a process. Again, this may be a good diagram to produce after the cause enumeration type has been done.

Instructor's Notes:

SUGGESTIONS FOR GROUP SESSIONS TO CONSTRUCT CAUSE-AND-EFFECT DIAGRAMS

1. ORGANIZE SESSIONS SO THAT EVERYONE PARTICIPATES
2. DON'T CRITICIZE IDEAS WHEN THEY ARE GENERATED
3. LET EVERYONE SEE THE CHART
4. GROUP CAUSES TOGETHER AS THEY ARE MENTIONED
5. DON'T OVERLOAD ANY ONE DIAGRAM. YOU MAY NEED TO BREAK IT DOWN INTO SMALLER DIAGRAMS IF ONE BRANCH HAS TOO MANY SUB BRANCHES
6. CIRCLE THE MOST LIKELY CAUSES.
7. AVOID SOLVING THE PROBLEMS OR FINDING THE RESPONSIBLE PERSON OR PEOPLE. THIS SESSION IS TO IDENTIFY ALL POSSIBLE CAUSES

- Briefly discuss these suggestions with the class, using examples when appropriate.

Instructor's Notes:

SUMMARY OF CAUSE-AND-EFFECT DIAGRAMS

- DEFINITION
- USES
- CONSTRUCTION
- EXAMPLES

- Use this slide to review the major points of Session 3.
- At this point you may wish to preview the Session 3 lab exercise.

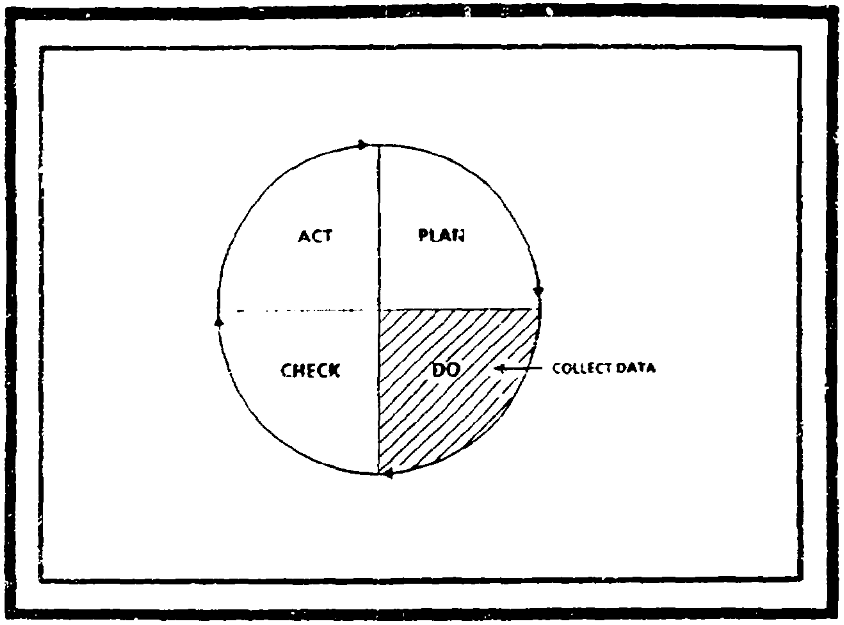
Instructor's Notes:

SESSION 4: DATA COLLECTION

DATA COLLECTION

- Review the Session 3 lab exercise.
- Introduce Session 4.

Instructor's Notes:



- Review the PDCA cycle.
- Data collection usually takes place during the Do phase of the PDCA cycle.
- Data collection will:
  - Facilitate informed decision making.
  - Document problems.
  - Show the effects of any improvements made.

Instructor's Notes:

WHAT WE'LL COVER IN SESSION 4

DATA COLLECTION

- DEFINITION
- TYPES
- WHY ARE DATA COLLECTED
- SAMPLING
- COLLECTION METHODS
- DATA ORGANIZATION
- POINTS TO REMEMBER

- Use this slide to preview Session 4.

Instructor's Notes:

DATA COLLECTION

- INFORMATION COLLECTED IN A SYSTEMATIC MANNER TO ANSWER SPECIFIC QUESTIONS
- TERMS ASSOCIATED WITH DATA COLLECTION
  - VARIABLE
  - DISCRETE
  - CONTINUOUS
  - SAMPLE
  - POPULATION
  - CHECKSHEETS

- Briefly define each of the terms that will be used in this session.
- "Variable" is a generic name for what you are measuring (e.g., thickness of plating in mm, plating tank temperatures, time to complete a job, or defects).
- These terms will be covered in more detail during the session.

Instructor's Notes:

DISCRETE DATA

- COUNTING
  - SEX
  - WAGE GRADE
  - ATTENDANCE
  - OCCUPATION
  - SHIFTS
  - DEFECT
  - TYPE OF AIRCRAFT

- Discrete data:
  - Provides information on things that are counted (*e.g.*, number of defects, number of awards, number of items in a tank).
- Give some additional examples of discrete data found at the NARF.
- Ask the class for some examples of discrete data.

Instructor's Notes:

CONTINUOUS DATA

- MEASUREMENT
  - TEMPERATURE
  - HEIGHT
  - WEIGHT
  - LENGTH
  - TIME
  - CONCENTRATION
  - DIAMETER

- Continuous data:
  - Information collected by taking measurements.
  - Provides detailed information about a variable (e.g., length, width, weight, temperature).
- Give some other examples of continuous data at the NARF.
- Ask the class for some examples of continuous data.
- The type of data you collect (discrete or continuous) will determine the type of graph you will use.

Instructor's Notes:

WHY ARE DATA COLLECTED?

- EVALUATE CAUSES AS A BASIS FOR ACTIONS AND DECISIONS
- TO ANALYZE AND UNDERSTAND PROBLEMS AND PROCESSES
- TO ORGANIZE, SUMMARIZE, AND DESCRIBE OUTCOMES OR PROCESSES
  - CONFORMANCE TO SPECIFICATIONS
  - TRENDS

- **Ishikawa defines data as the basis for decision making.**
- **Data will help you to understand how a job is accomplished.**
- **Data collection will help to minimize differences of opinion.**
- **Use NARF-related examples to illustrate these points.**

Instructor's Notes:

SAMPLING

- SAMPLE DATA ARE USED TO ESTIMATE A POPULATION

  POPULATION – ALL POSSIBILITIES

  - EVERYONE WORKING AT THE NARF
  - 100% INSPECTION C   PRODUCT

- SAMPLE – A SUBSET OF THE POPULATION

  - EVERY FIF   PERSON AT THE NARF
  - INSPECTI   EVERY FOURTH PRODUCT

- Provide the class with **NARF**-related examples of these terms.

  - Population (e g., 100% inspection of cars to see if they have legitimate DoD stickers before entering the base).

  - Sample of the population (e.g., the RISK system which chooses work to be checked).

- For most situations, samples give you a good insight into the population (e.g., samples of registered voters can be used to predict general election results).

Instructor's Notes:

METHODS FOR AVOIDING A BIASED SAMPLE - RANDOM SAMPLING - STRATIFIED RANDOM SAMPLING

- Bias occurs when the sample doesn't reflect the population.
- Give a NARF-related example of how a sample can be biased (e.g., if quality checks were made only on Thursdays).
- Bias can be reduced by systematic data collection.
- Random sampling - selecting a sample such that every element in the population has an equal chance of being selected.
- Stratified random sampling:
  - Random sample from subgroups within the populations.
  - For example, if 43% of the workload (population) is hingepins, then 43% of your sample should be hingepins.

Instructor's Notes:

COLLECTION METHODS

- DIRECT OBSERVATION
- INTERVIEWS
- SURVEYS
- EXISTING INFORMATION

- The choice of which data collection method to use will depend on your particular project.
- Point one: Examples include checksheets, work diaries.
- Point two: Contrast open-ended interviews with forced choice interviews.
- Point three: A written opinion poll.
- Point four: Quality assurance or production status information.

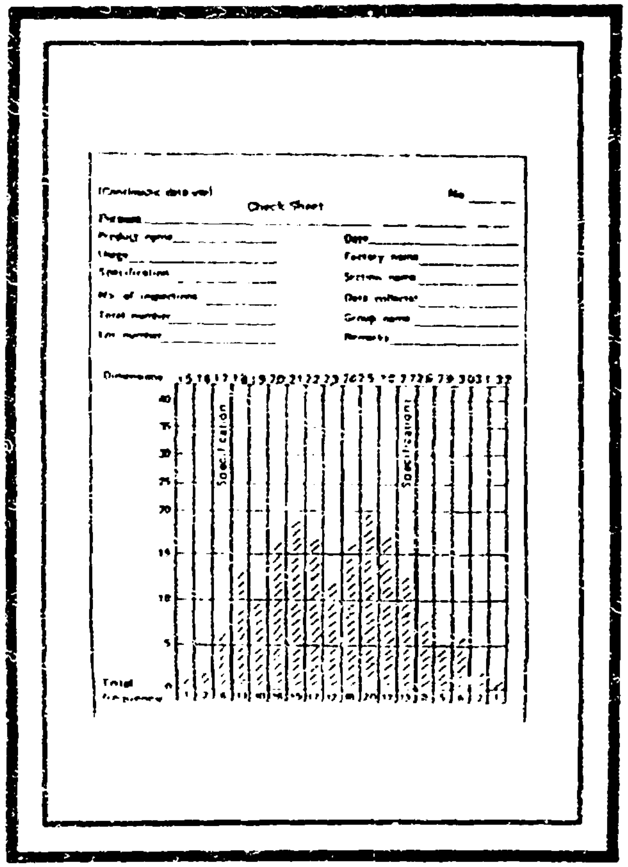
Instructor's Notes:

DATA ORGANIZATION

- ACCURATE
- SYSTEMATIC
- DOCUMENTED

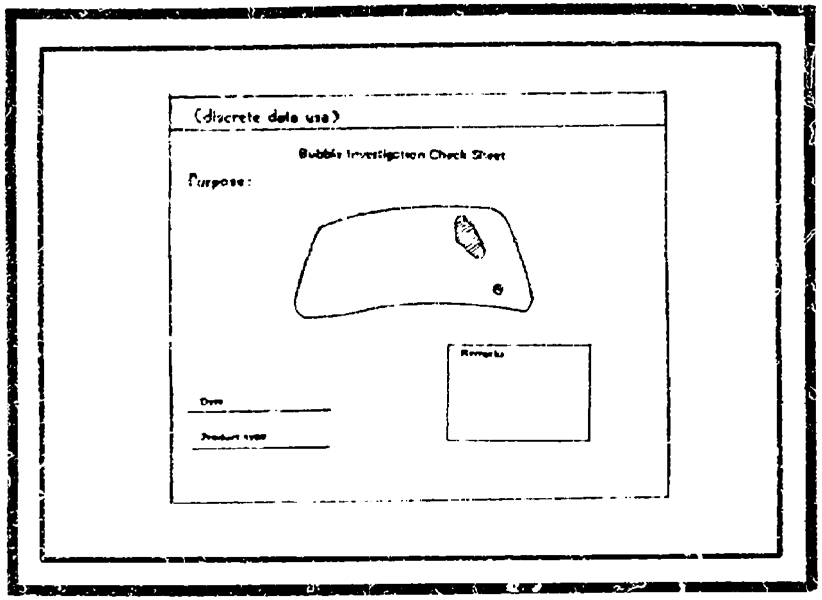
- All projects depend on data that are accurately observed, measured, and recorded.
- It is important to provide appropriate labeling and supporting information on the data collection forms.

Instructor's Notes:



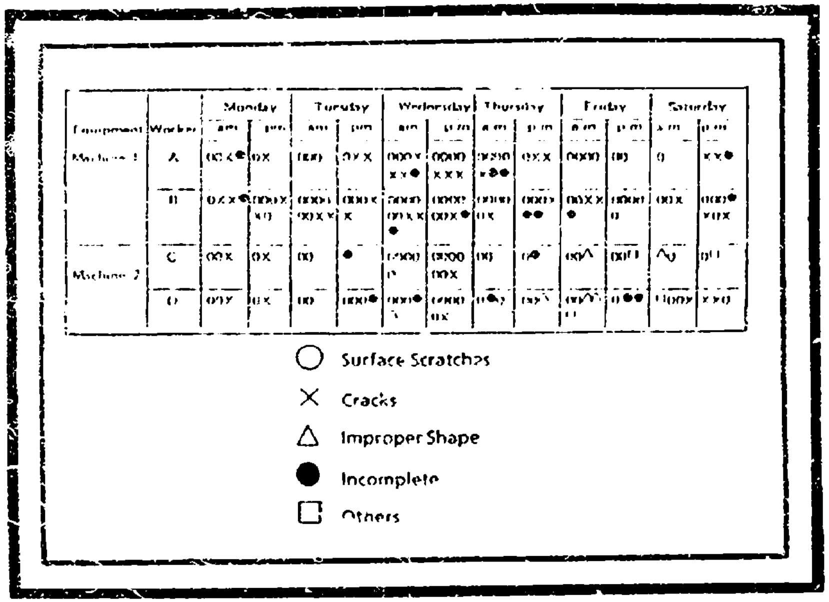
- The next four slides are examples of different types of checksheets (there can be many others).
- Explain the purpose and type of information on each checksheet, including data type (discrete or continuous).
- Point out similarities and differences in the forms.
- This checksheet sorts data by part dimension.

Instructor's Notes:



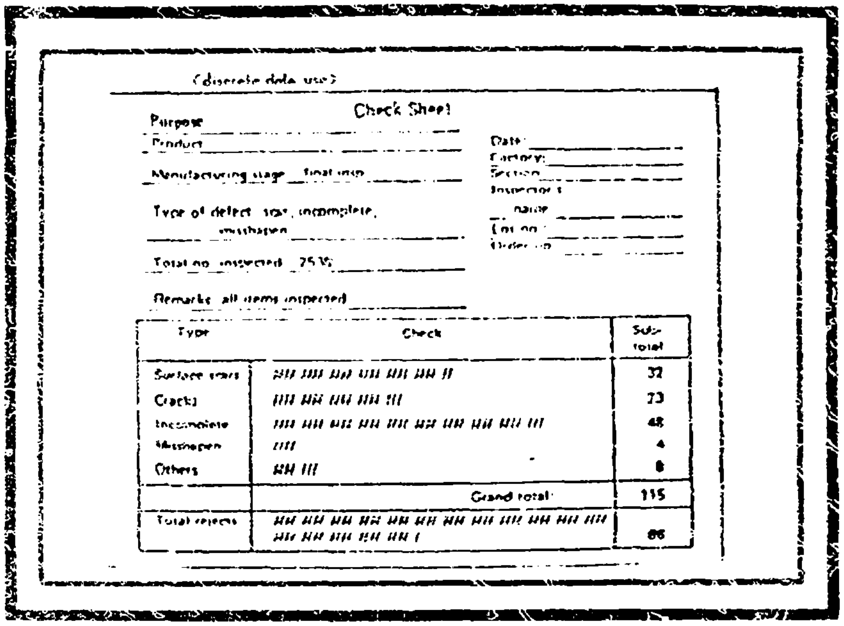
- This checksheet is a diagram of the part being checked.
- To use it, mark the spots where defects occur.

Instructor's Notes.



- This is a checksheet of defects as they relate to four different variables: equipment, worker, day, shift.
- What does this checksheet tell you about the different variables?

Instructor's Notes:



(discrete data use)

Check Sheet

Purpose ______
Product ______
Manufacturing stage final insp.
Type of defect scar, incomplete, misshapen
Total no. inspected 2530
Remarks all items inspected

Date:
Factory:
Section:
Inspector's name
Lot no.
Order no.

Type	Check	Sub-total
Surface scars	//// //// //// //// //// //// //	32
Cracks	//// //// //// //// ///	23
Incomplete	//// //// //// //// //// //// //// //// //// ///	48
Misshapen	////	4
Others	//// ///	8
	Grand total:	115
Total rejects	//// //// //// //// //// //// //// //// //// //// //// //// //// //// //// //// //// /	86

- This is a checksheet of types of defects.
- No reasons are given for why each part was rejected (the numbers don't match up). Is it important to know this?

Instructor's Notes:

POINTS TO REMEMBER

- HAVE A CLEAR PURPOSE
- HAVE A DATA COLLECTION PLAN
- DOCUMENT WITH ACCURACY

- Point one: Know why you are collecting these data.
- Point two: Specify your sampling and data collection plan.
- Point three: Use clearly defined checksheets. Note the variable being measured, the days that measures are taken, and other important considerations on the checksheet.

Instructor's Notes:

SUMMARY OF DATA COLLECTION

- DEFINITION
- TYPES
- WHY DATA ARE COLLECTED
- SAMPLING
- COLLECTION METHODS
- DATA ORGANIZATION
- POINTS TO REMEMBER

- Use this slide to review the major points in Session 4.
- At this point you may wish to preview the Session 4 lab exercise.

Instructor's Notes:

SESSION 5: PARETO DIAGRAMS

PARETO DIAGRAMS

- Review the Session 4 lab exercise.
- Introduce Session 5.

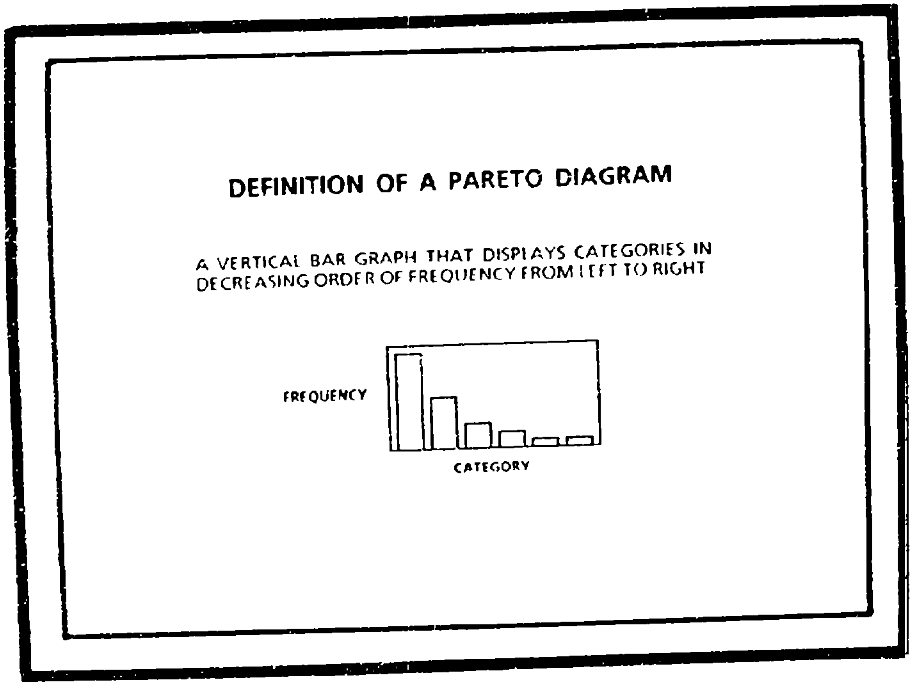
Instructor's Notes:

WHAT WE'LL COVER IN SESSION 5

- WHICH GRAPHIC TOOL DO WE USE?
- PARETO DIAGRAMS
  - DEFINITION
  - USE
  - TERMS
  - INTERPRETATION
  - CONSTRUCTION
  - PRACTICAL APPLICATIONS

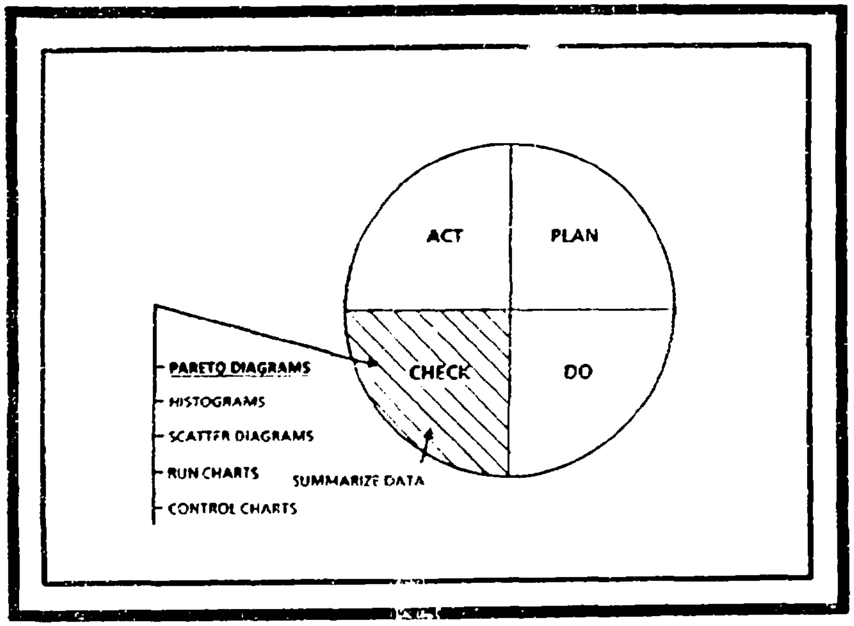
- Use this slide to preview Session 5.

Instructor's Notes:



- Use this slide to briefly review the form and definition of a Pareto diagram.

Instructor's Notes:



- Review the PDCA cycle.
- Pareto diagrams are most frequently used during the Check phase of the PDCA cycle.
- The main portion of this session will focus on how to summarize data with Pareto diagrams.

Instructor's Notes:

WHICH GRAPHIC TOOL DO WE USE?

- DEPENDS ON QUESTIONS ASKED
- DEPENDS ON THE INTENDED USE OF THE INFORMATION
- DEPENDS ON THE TYPE OF DATA

- The basic graphic methods are tools that help to increase your understanding of a process.

Instructor's Notes:

COMMON ORGANIZATIONAL QUESTIONS

- WHAT ARE OUR MOST IMPORTANT PROBLEMS?
- WHAT PROBLEMS DO WE NEED TO FOCUS ON FIRST?

- These questions are a starting point for looking at a process.
- Ask the class what happens when two people disagree on a problem.
  - Does the person with the higher rank win?
  - How do you know who is really correct?
  - Pareto diagrams can help you to answer these questions objectively.

Instructor's Notes:

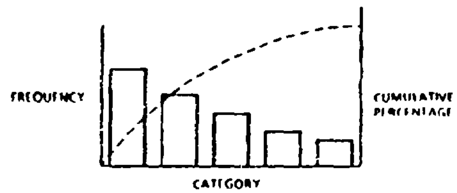
PARETO DIAGRAMS

- RANK PROBLEMS
- PRIORITIZE
- USE DISCRETE DATA

- Use this slide to guide the discussion of how Pareto diagrams help to answer the common organizational questions.

Instructor's Notes:

PARETO DIAGRAM



- TERMS ASSOCIATED WITH PARETO DIAGRAMS
  - FREQUENCY
  - PERCENTAGE
  - BARS
  - VERTICAL AXIS
  - HORIZONTAL AXIS
  - CUMULATIVE PERCENTAGE LINE

- Briefly review the diagrams and the terms.
- The cumulative percentage line is optional. It sums the percentages for each category, moving from left to right.
- The steeper a cumulative percentage line, the greater the difference between categories.

Instructor's Notes:

BRIEF HISTORY

- VILFREDO PARETO
- J. M. JURAN
  - "vital few . . . trivial many"

- Pareto diagrams were named for an Italian economist, Vilfredo Pareto.
  - Pareto studied the distribution of personal income.
  - He found most of the wealth was centered in a few occupations.
- Juran expanded the use of Pareto diagrams and coined the phrase "vital few, trivial many."
- Give the students an example of "vital few, trivial many" using NARF data.

Instructor's Notes:

Equipment	Worker	Monday am	Monday pm	Tuesday am	Tuesday pm	Wednesday am	Wednesday pm	Thursday am	Thursday pm	Friday am	Friday pm	Saturday am	Saturday pm
Machine 1	A	00X●	0X	000	0XX	000X XX●	0000 XXX	0000 X●●	0XX	0000	00	0	XX●
	B	0XX●	000X X0	0000 00XX	000X X	0000 00XX ●	0000 00X●	0XXX 0X	000X ●●	00XX ●	0000 0	00X	000● X0X
Machine 2	C	00X	0X	00	●	0000 0	0000 00X	00	0●	00△	00[illegible]	△0	0[illegible]
	D	00X	0X	00	000●	000● △	0000 0X	0●0	00△	00△△ [illegible]	0●●	000X	XX0

○ Surface Scratches

× Cracks

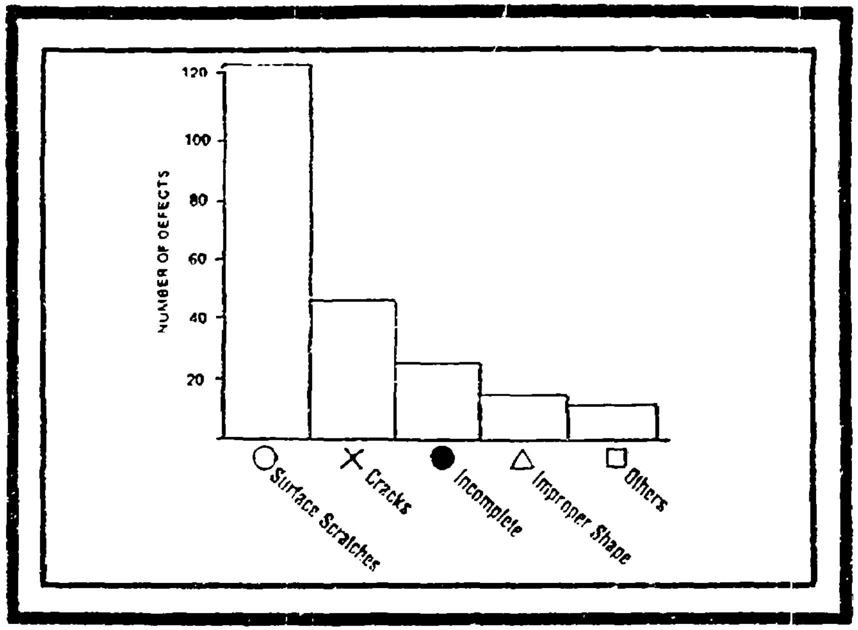
△ Improper Shape

● Incomplete

□ Others

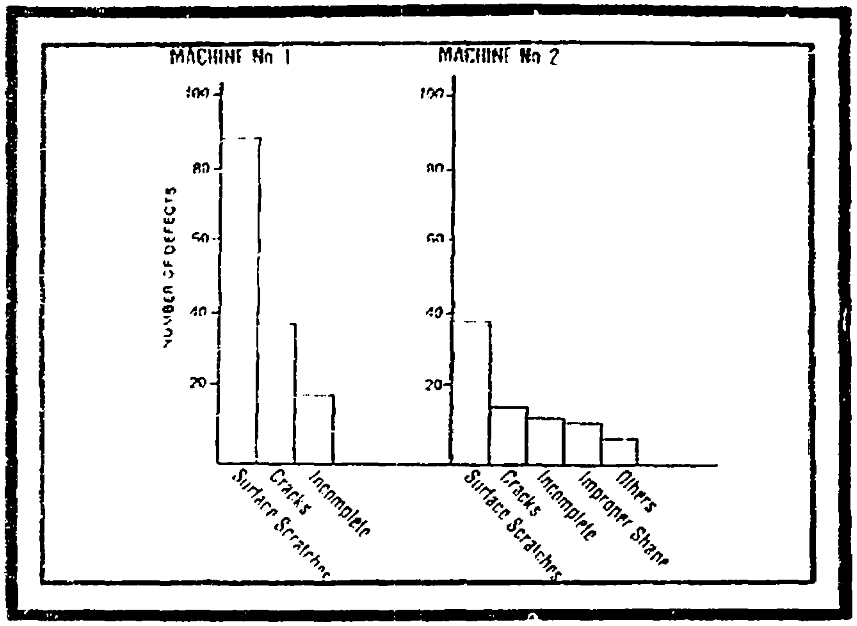
- The next five slides ... demonstrate some advantages to using the basic graphic methods. You can substitute NARF-related examples if you wish.
- Note that this table is difficult to interpret.

Instructor's Notes:



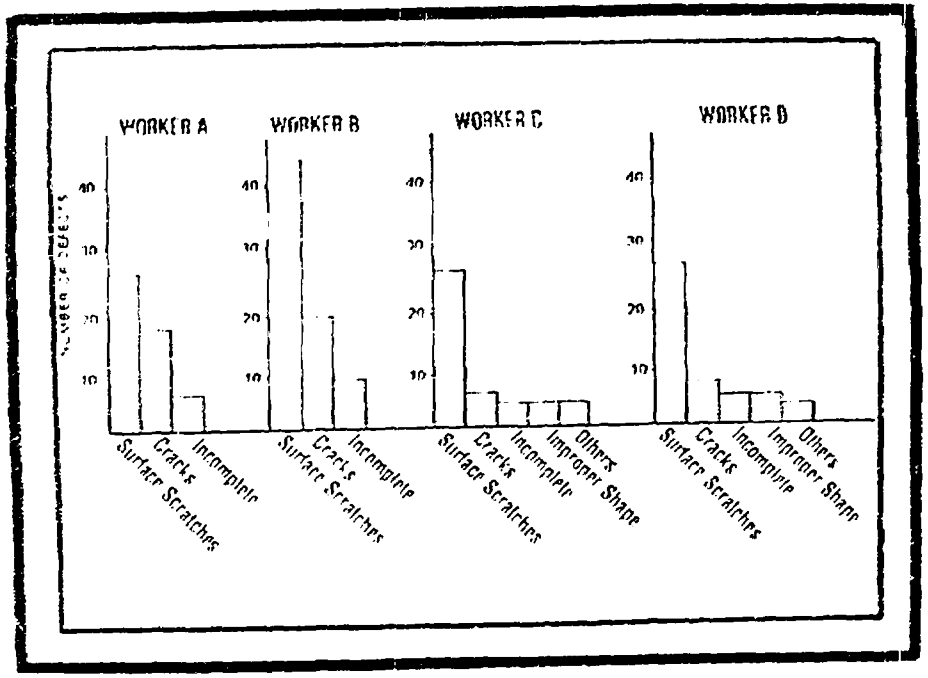
- This Pareto diagram sorts the information by defect.
- Ask the class what the Pareto diagram tells them about the defects (most are surface scratches).

Instructor's Notes:



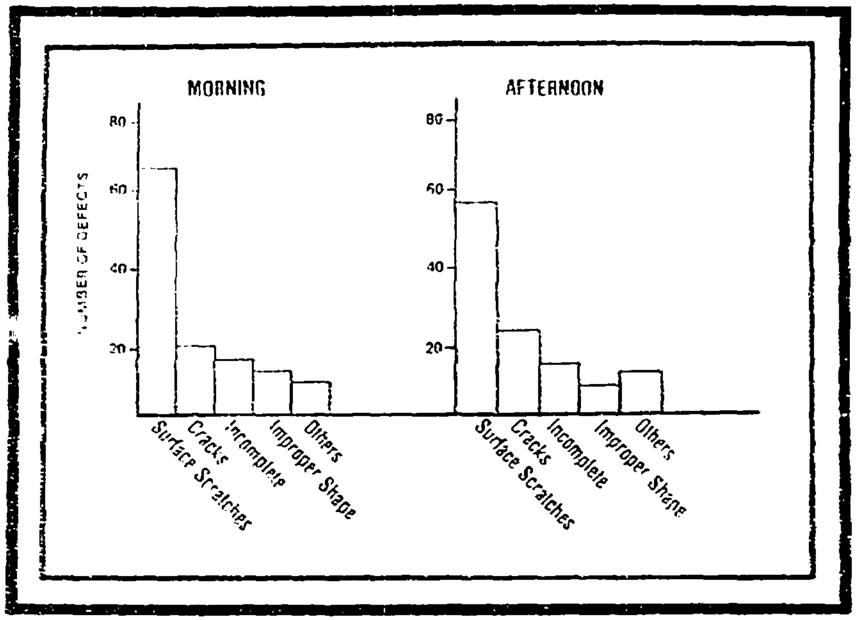
- These Pareto diagrams of defects sorted by machine number yield additional information.
- Ask the class to interpret the Pareto diagrams. (Machine number 1 produces more defects.)
- Ask the class why machine number 1 might be responsible for the defects (out of alignment, etc.).

Instructor's Notes:



- These Pareto diagrams sort defects by worker.
- Ask the class to interpret these Pareto diagrams, (worker B is producing more surface scratches).
- Ask the class why worker B is producing more errors.
  - Is he or she using machine 1?
  - Is he or she producing more pieces?
  - Is he or she new?
- Ask the class when the percentage of defects would be a better measure than the number of defects (when the number of pieces differed for each worker).

Instructor's Notes:



- These Pareto diagrams sort defects by shift.

- Ask the class to interpret the Pareto diagrams. There are no apparent differences.

- Remind the class that graphic techniques don't solve problems, they help to organize information. In order to solve problems the information must be evaluated and acted upon.

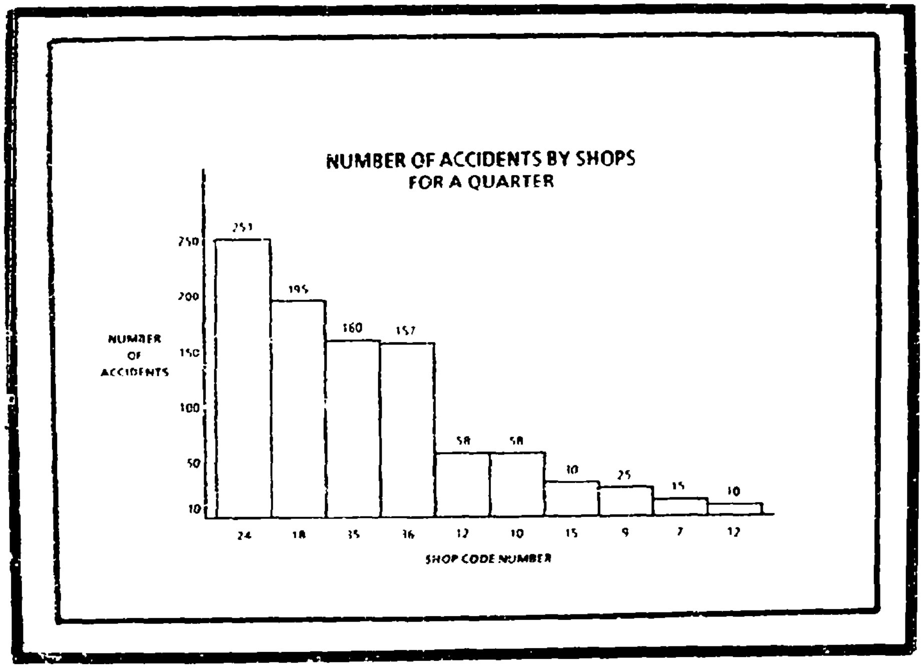
Instructor's Notes:

HOW TO CONSTRUCT PARETO DIAGRAMS

1. DETERMINE CATEGORIES
2. DEVELOP WAYS TO SYSTEMATICALLY COLLECT DATA - SUCH AS CHECKSHEETS
3. COMPUTE FREQUENCIES
4. RANK THE CATEGORIES
5. GRAPH THE CATEGORIES BY RANK
   a. CATEGORIES ON THE HORIZONTAL AXIS
   b. FREQUENCIES ON THE VERTICAL AXIS
6. LABEL DIAGRAM
   a. TITLE
   b. PERIOD COVERED
   c. DATA COLLECTOR
7. DETERMINE AND GRAPH CUMULATIVE PERCENTAGES (OPTIONAL)

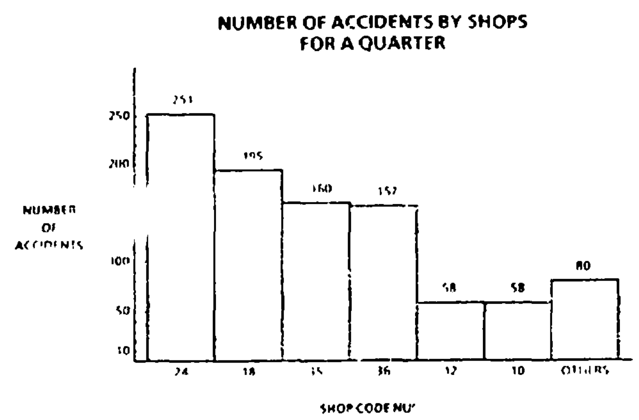
- Work through these steps using the following example or substitute a NARF-related example.

Instructor's Notes:



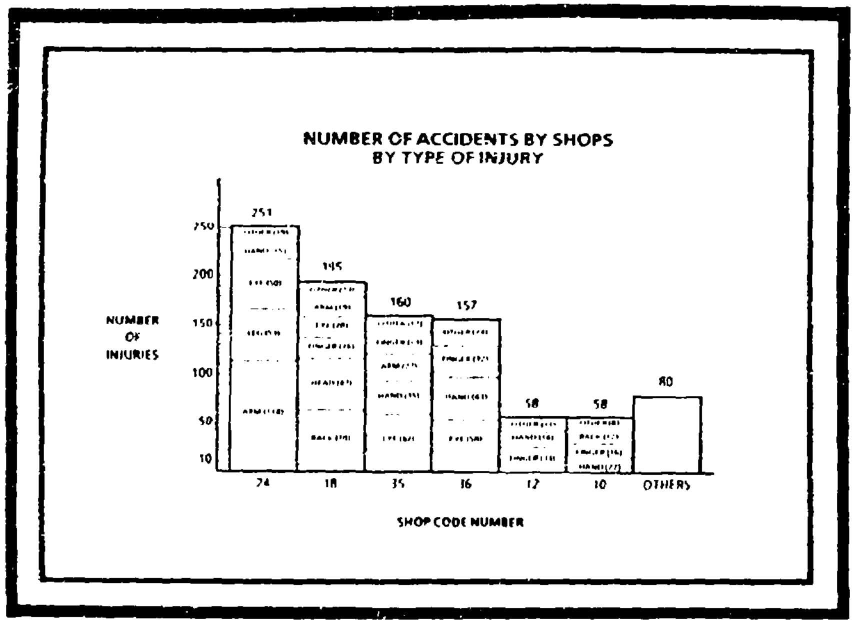
- The next four slides use fictional data. You may wish to substitute NARF-related examples for this series.
- Review the parts of the graph.
- The purpose of this graph is to help identify the number of accidents occurring within each shop.
- Help the class interpret the Pareto diagram.
  - Is this information useful?
  - Are there too much or too little data?

Instructor's Notes:



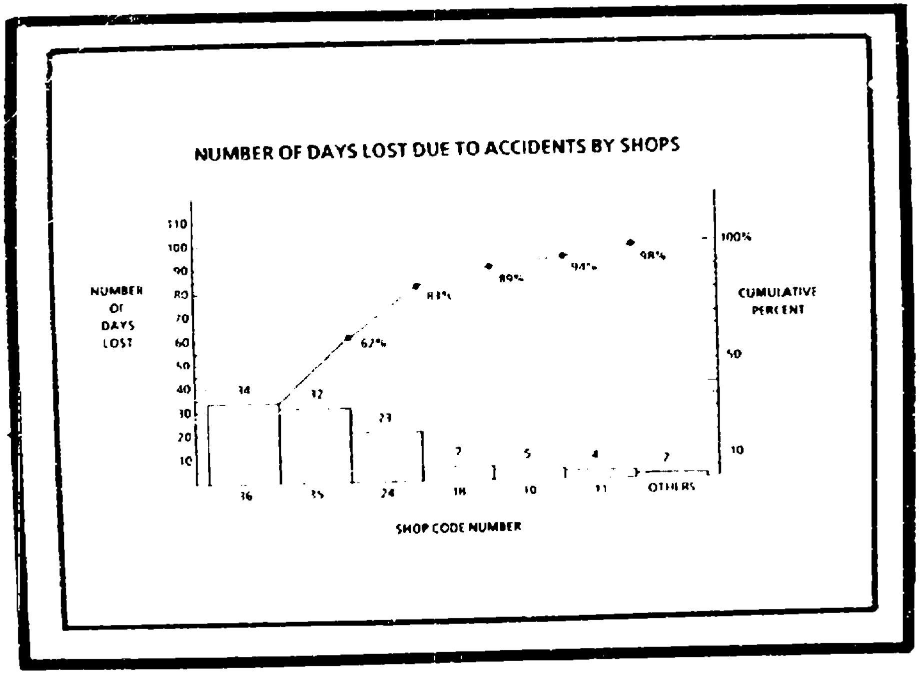
- This graph illustrates how data reduction can result in a clearer picture.
- Help the class interpret the data.
  - Is this information useful?
  - What other information might be useful (e.g., type of injury, severity of injury)?

Instructor's Notes:



- This Pareto diagram details the types of injuries that occurred.
- It also orders them within each shop according to frequency of occurrence.
- Help the class to interpret the added information.
  - Is knowing the type of injury useful?
  - What type of injury seems to occur most often?
  - What additional information would be needed to reduce the most frequent injury (e.g., nature of work related to eye injury)?

Instructor's Notes:



- When the variable of interest is the number of days lost due to accidents, the order of the shops (categories) changes.
- Note the use of the cumulative percentage line.

Instructor's Notes:

CHOOSING THE DATA TO BE GRAPHED

- REMEMBER YOUR PURPOSE
- PROGRESSIVE ANALYSIS

- Point one: Keep in mind the questions you are trying to resolve when you chose the variables to graph. Use other graphic tools such as the cause-and-effect diagram to help you pick the relevant variables.

- Point two: Examination of a Pareto diagram may raise new questions as well as answer the original one. Resorting the data or collecting new data to try and answer these questions is called progressive analysis.

Instructor's Notes:

PRACTICAL APPLICATIONS OF PARETO DIAGRAMS

- IDENTIFICATION OF MAJOR PROBLEM AREAS
- RELATIONSHIP TO CAUSE-AND-EFFECT DIAGRAM
- BEFORE AND AFTER COMPARISONS
- EMPLOYEE FEEDBACK
- REPORTS AND PRESENTATIONS

- Briefly review these points using examples shown earlier. You may also wish to substitute NARF-related examples.

Instructor's Notes:

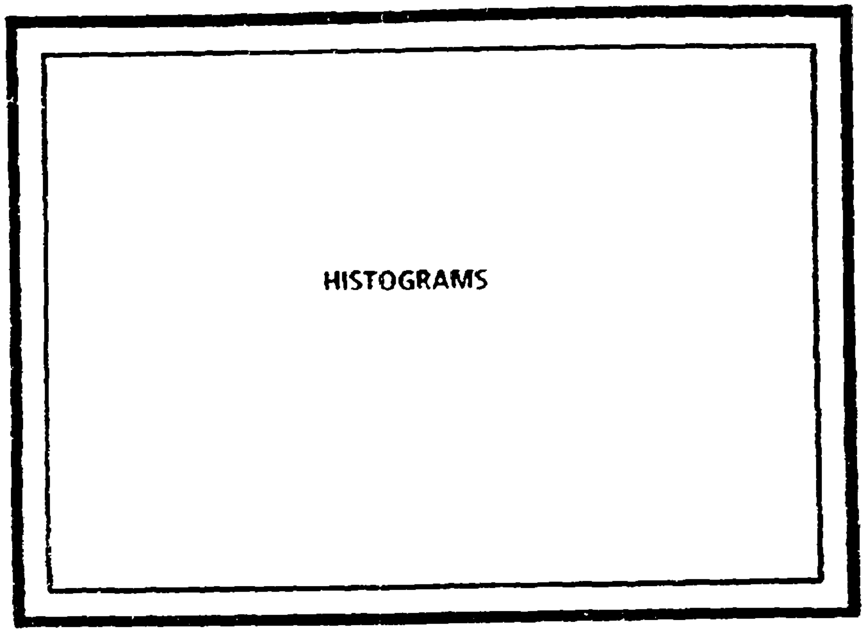
SUMMARY OF PARETO DIAGRAMS

- USES
- DEFINITION
- TERMS
- INTERPRETATION
- CONSTRUCTION
- PRACTICAL APPLICATIONS

- Use this slide to review the major points of Session 5.
- At this point preview the Session 5 lab exercise.

Instructor's Notes:

SESSION 6: HISTOGRAMS



- Review the Session 5 lab exercise.
- Introduce Session 6.

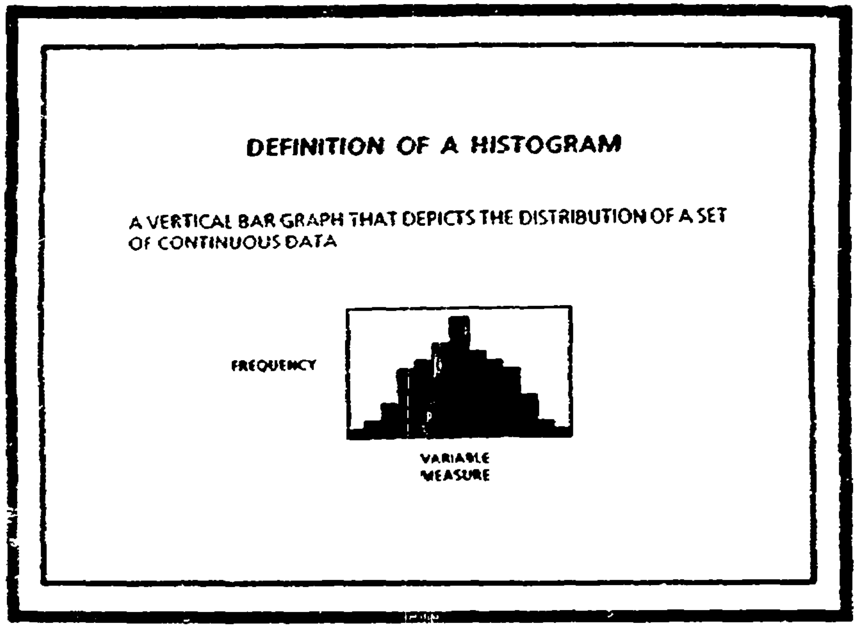
Instructor's Notes:

WHAT WE'LL COVER IN SESSION 6

- HISTOGRAMS
  - DEFINITION
  - USES
  - CONSTRUCTION
  - INTERPRETATION
  - VARIATIONS

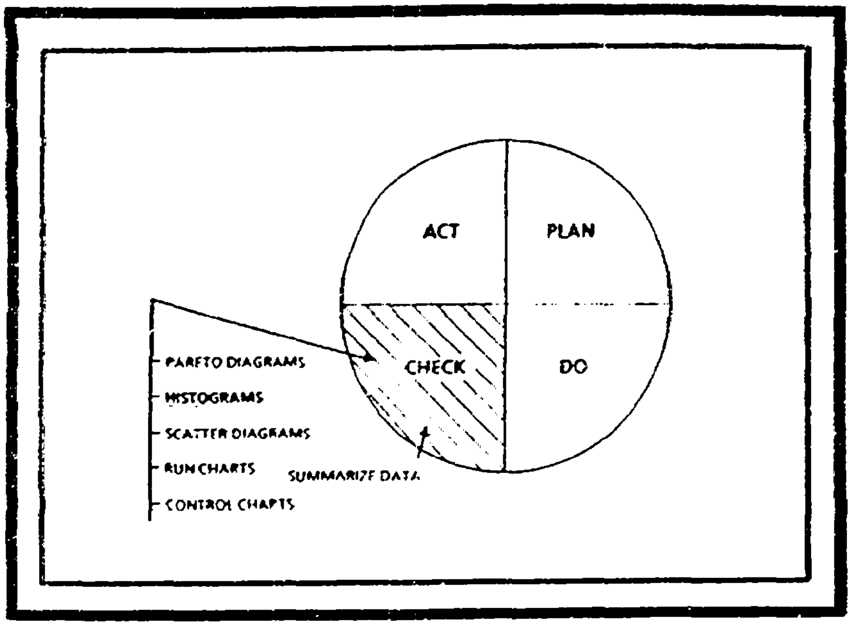
- Use this slide to preview Session 6.

Instructor's Notes:



- Use this slide to briefly review the form and definition of a histogram.

Instructor's Notes:



- Review the PDCA cycle.
- Histograms are most often used in the Check phase of the PDCA cycle.

Instructor's Notes:

DATA TYPES AND DISTRIBUTIONS

- DISCRETE DATA
  - CATEGORIES (PARETO DIAGRAM)
  - DISTRIBUTION OF RANKED FREQUENCIES
- CONTINUOUS DATA
  - MEASUREMENT (HISTOGRAM)
  - DISTRIBUTION OF CONTINUOUS FREQUENCIES

- Review the differences between discrete and continuous data using NARF-related examples.

Instructor's Notes:

Metal block thickness (in mm)

Data										x_L	x_S
3.56 o	3.46	3.48	3.50	3.42 x	3.43	3.52	3.49	3.44	3.50	3.56	3.42
3.48	3.56 o	3.50	3.52	3.47	3.48	3.46	3.50	3.56	3.38 x	3.56	3.38
3.41	3.37 x	3.47	3.49	3.45	3.44	3.50 o	3.49	3.46	3.46	3.50	3.37
3.55 o	3.52	3.44 x	3.50	3.45	3.44	3.48	3.46	3.52	3.46	3.55	3.44
3.48	3.48	3.37	3.40	3.52 o	3.34	3.46	3.43	3.30 x	3.46	3.52	3.30 x
3.59	3.63 o	3.59	3.47	3.38	3.52	3.45	3.48	3.31 x	3.46	3.63	3.31
3.40 x	3.54	3.46	3.51	3.48	3.50	3.68 o	3.60	3.46	3.52	3.68 o	3.40
3.48	3.50	3.56 o	3.50	3.52	3.46 x	3.48	3.46	3.52	3.56	3.56	3.46
3.52	3.48	3.46	3.45	3.46	3.54 o	3.54	3.48	3.49	3.41 x	3.54	3.41
3.41	3.45	3.34 x	3.44	3.47	3.47	3.41	3.48	3.54 o	3.47	3.54	3.34

o: The largest value in the row

x: The smallest value in the row

$N = 100$, $x_L = 3.68$

$x_S = 3.30$

- This example of a large data set comes from Ishikawa, p. 8 (thickness of metal blocks).
- X sub L is the largest value of all the data, reading from left to right.
- X sub S is the smallest value of all the data.
- Note that the data are not very informative in this form.

Instructor's Notes:

WAYS TO SUMMARIZE LARGE DATA SETS

- CONSTRUCT A FREQUENCY DISTRIBUTION FOR THE OBSERVATIONS
- GROUP SCORES INTO INTERVALS AND CONSTRUCT A FREQUENCY DISTRIBUTION FOR THOSE INTERVALS

- Briefly review these suggestions for summarizing data sets.
- Point one: Frequency refers to the number of times an observation occurs.
- Point two: A *frequency distribution* shows the number of observations in each interval or category.

Instructor's Notes:

FREQUENCY DISTRIBUTION OF METAL BLOCK THICKNESS (in mm)

VALUES	FREQUENCY TALLY	FREQUENCY
3.30	I	1
3.31	I	1
3.32	I	1
3.34	II	2
3.37	I	1
3.38	II	2
3.40	II	2
3.41	IIII	4
3.42	I	1
3.43	II	2
3.44	卌	5
3.45	卌	5
3.46	卌 卌 卌	15
3.47	卌 I	6
3.48	卌 卌 III	13
3.49	IIII	4
3.50	卌 IIII	9
3.51	I	1
3.52	卌 卌	10
3.54	IIII	4
3.55	I	1
3.56	卌	5
3.59	II	2
3.60	I	1
3.63	I	1
3.68	I	1
	TOTAL N	= 100

- This is an example of a frequency distribution using the metal block data shown earlier.
- Compare the frequency distribution with the table containing the raw data.

Instructor's Notes:

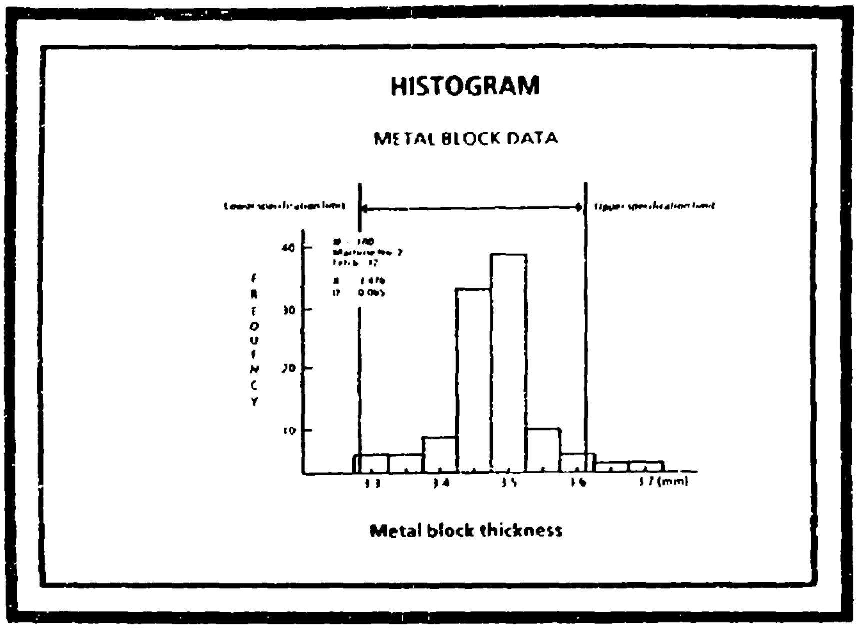
EXAMPLE OF A FREQUENCY DISTRIBUTION WITH SCORES GROUPED INTO INTERVALS

Class no.	Class boundaries		Mid value	Frequency tally	Frequency
1	3.275	3.325	3.30	|||	3
2	3.325	3.375	3.35	|||	3
3	3.375	3.425	3.40	卌 ||||	9
4	3.425	3.475	3.45	卌 卌 卌 卌 卌 卌 |||	33
5	3.475	3.525	3.50	卌 卌 卌 卌 卌 卌 卌 ||	37
6	3.525	3.575	3.55	卌 卌	10
7	3.575	3.625	3.60	|||	3
8	3.625	3.675	3.65	|	1
9	3.675	3.725	3.70	|	1

$N = 100$

- This is an example of a frequency distribution grouped into intervals, called class boundaries here, using the metal block data shown earlier.
- Compare this graph with the frequency distribution on the previous slide.

Instructor's Notes:



- If we take the previous form and graph it, we get this histogram.
- The shape of the histogram can tell you how consistent and predictable the process outcome is.

Instructor's Notes:

WHY ARE HISTOGRAMS USED?

- SUMMARIZE DATA
- SIMPLIFY EXPLANATION OF DATA
- USEFUL COMMUNICATION TOOL

- Briefly summarize these points.

Instructor's Notes:

HOW TO CONSTRUCT A HISTOGRAM

1. COLLECT AND RECORD SAMPLE DATA
2. IDENTIFY LARGEST (X_L) AND SMALLEST (X_S) VALUE
3. COMPUTE THE RANGE

   $R = X_L - X_S$

4. DETERMINE THE NUMBER OF CLASSES (K)

NUMBER OF DATA	NUMBER OF CLASSES (K)
LESS THAN 50	5 - 7
50 - 100	6 - 10
101 - 250	7 - 12
OVER 250	10 - 20

- The next two slides explain the standard way to construct a histogram.
- Within this structure, there are some choices to make (e.g., the number of intervals in the histogram).
- Explain how to use the chart to determine the total number of intervals (the chart comes from Ishikawa, p. 9).

Instructor's Notes:

HOW TO CONSTRUCT A HISTOGRAM

5. COMPUTE THE CLASS INTERVAL (H)

$$H = \frac{X_L - X_S}{K - 1}$$

6. DETERMINE THE CLASS BOUNDARIES
   a. LEFTMOST CLASS BOUNDARY = $X_S - (1/2 \times H)$
   b. ALL OTHER BOUNDARIES ARE COMPUTED BY ADDING THE VALUE OF THE CLASS INTERVAL (H) TO THE PREVIOUS CLASS BOUNDARY VALUE
7. TALLY THE FREQUENCIES WITHIN EACH CLASS
8. DRAW IN THE BARS FOR THE HISTOGRAM

- Computing the class interval (H) gives you the width of the interval.
- The width of the interval will depend on the range of values and the number of classes.
- Class boundary formula assures that data points will not fall exactly on a border.

Instructor's Notes:

POINTS TO CONSIDER WHEN CONSTRUCTING HISTOGRAMS

- NUMBER OF INTERVALS
- SIZE OF INTERVALS
- SETTING BOUNDARIES

- These are the factors that will determine how the histogram will look.
- They are dependent on the sample size and range of data.

Instructor's Notes:

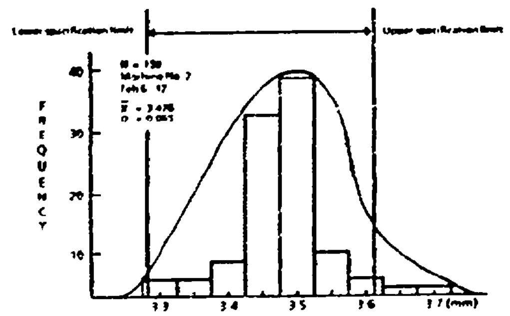
HOW ARE HISTOGRAMS USED?

- TO DEPICT THE VARIATION IN PROCESS OUTPUT
- TO COMPARE SAMPLE RESULTS WITH SPECIFICATIONS
- TO IDENTIFY FACTORS THAT CONTRIBUTE TO PROBLEMS
- TO FACILITATE IDENTIFICATION OF CAUSES OF VARIATION

- **Briefly review these points.**

Instructor's Notes:

HISTOGRAM WITH DISTRIBUTION CURVE



Metal block thickness

- This is a histogram of the metal block data shown earlier. It has the specification limits and distribution curve drawn in (optional).
- The shape of the distribution curve gives you additional information about the manufacturing process.
- Note that this distribution is not centered. The "tail" at the upper end is long, indicating that more metal blocks are being produced near the upper specification limits.

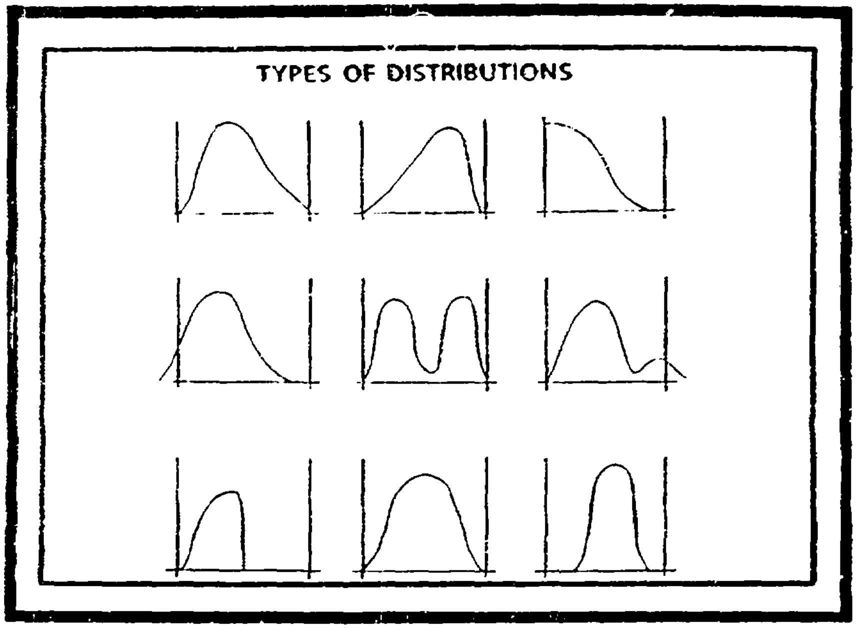
Instructor's Notes:

HOW DISTRIBUTIONS DIFFER

- CENTRAL TENDENCY
- PEAKEDNESS
- SKEWNESS

- **Briefly review these characteristics of distributions.**
- **Point one: Mean, median, mode.**
- **Point two: A measure of variability; how uniform.**
- **Point three: A measure of variability; how symmetrical the distribution is.**

Instructor's Notes:



- Discuss the information gained from each of these distributions and their specification lines.
- When possible, relate the examples to work done at the NARF.
- Ask the class for their interpretations of the distributions.

Instructor's Notes:

SOURCES OF VARIATION

- MATERIAL DIFFERENCES
- WORKER DIFFERENCES
- EQUIPMENT DIFFERENCES
- PROCESS DIFFERENCES
- THINGS BEYOND OUR CONTROL

- Briefly review these sources of variation.
- *Ask the class for* **NARF***-related examples.*

Instructor's Notes:

SUMMARY OF HISTOGRAMS

- DEFINITION
- USES
- CONSTRUCTION
- INTERPRETATION
- VARIATION

- Use this slide to review the major points of Session 6.
- At this point you may wish to preview the Session 6 lab exercise.

Instructor's Notes:

SESSION 7: SCATTER DIAGRAMS

SCATTER DIAGRAMS

- Review the Session 6 lab exercise.
- Introduce Session 7.

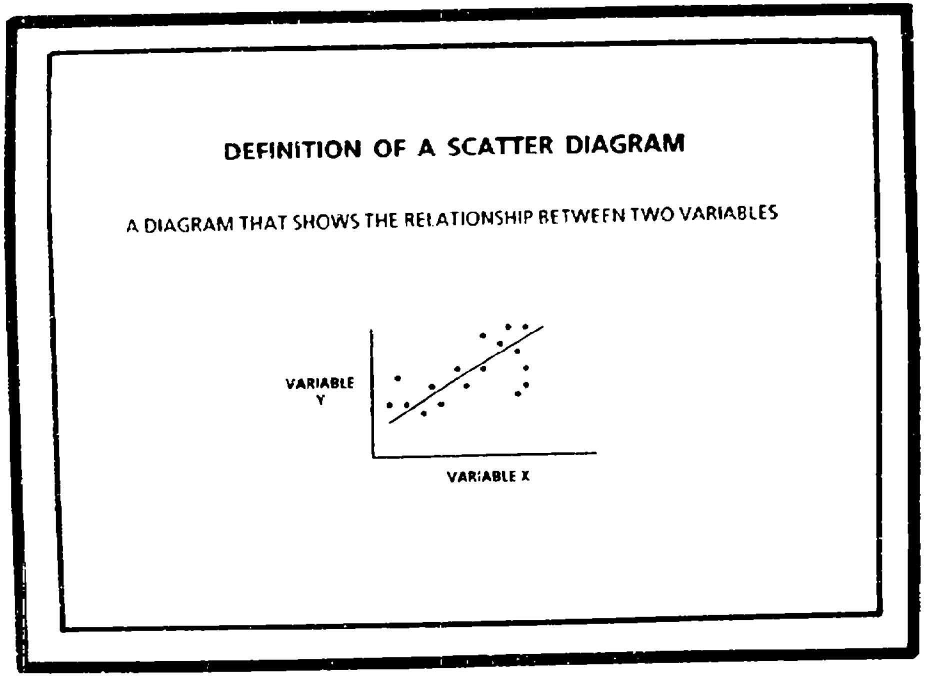
Instructor's Notes:

WHAT WE'LL COVER IN SESSION 7

- WAYS TO SUMMARIZE DATA
- SCATTER DIAGRAMS
  - DEFINITION
  - USE
  - INTERPRETATION – CORRELATIONS
  - CAUTION
  - CONSTRUCTION
  - SUMMARY
  - EXERCISES

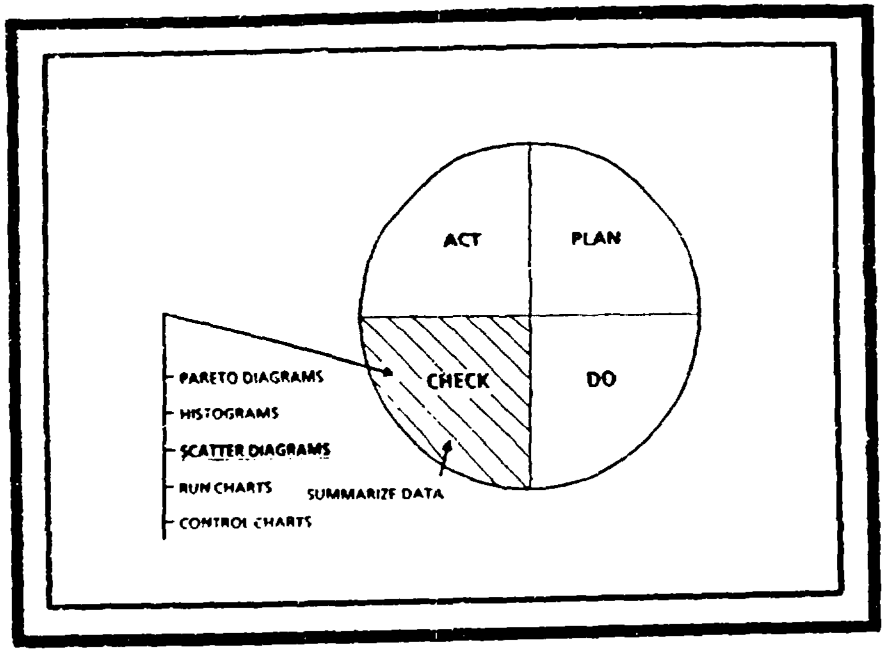
- Use this slide to preview Session 7.

Instructor's Notes:



- Use this slide to briefly review the form and definition of a scatter diagram.

Instructor's Notes:



- Review the PDCA cycle.
- Scatter diagrams are most frequently used during the Check phase of the PDCA cycle.

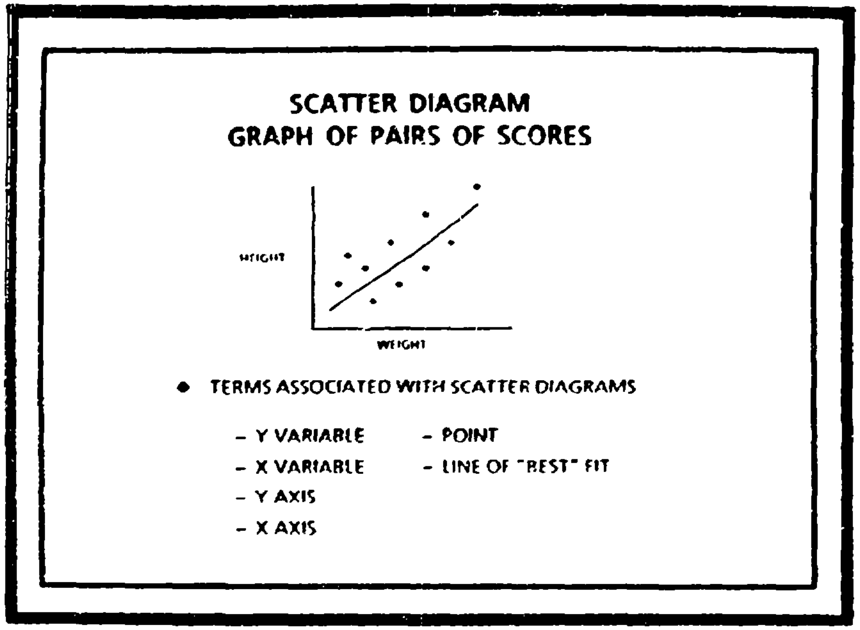
Instructor's Notes:

WAYS TO SUMMARIZE DATA

- ONE VARIABLE
  - DISCRETE DATA (PARETO DIAGRAM)
  - CONTINUOUS DATA (HISTOGRAM)
- TWO VARIABLES
  - CONTINUOUS DATA (SCATTER DIAGRAM)

- Review the definitions of discrete and continuous data using NARF-related examples.
- Give examples of situations where two variables are compared.
  - Height and weight.
  - Temperature and evaporation rate.

Instructor's Notes:



- Briefly review the diagram and the terms.
- Both of the variables should be collected at the same time.
- X axis - horizontal axis.
- Y axis - vertical axis.
- Line of best fit - estimates the shape of the plotted points and is usually determined mathematically.

Instructor's Notes:

USES OF SCATTER DIAGRAMS

- TO DEPICT THE RELATIONSHIP BETWEEN TWO VARIABLES
- TO DETECT A PATTERN AS TWO VARIABLES CHANGE OVER TIME
- TO EXAMINE WHAT IS THOUGHT TO BE A CAUSE-AND-EFFECT RELATIONSHIP
- TO UNCOVER AN EASY TO MEASURE INDICATOR OF A HARD-TO MEASURE VARIABLE

- Briefly review these points.
- Give some NARF-related examples (e.g., once you notice that the traffic on the bridge is related to the time of day, you can predict the crossover time by looking at your watch).

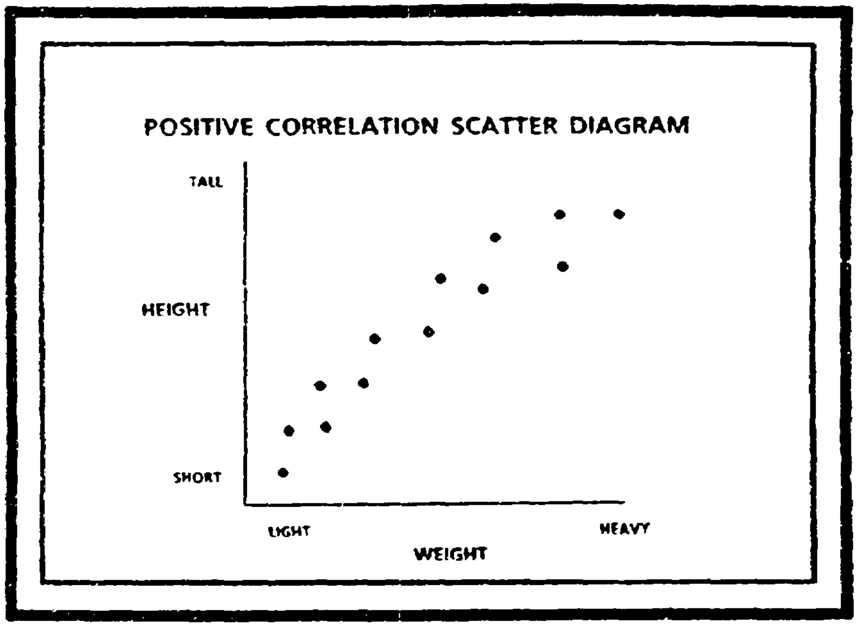
Instructor's Notes:

INTERPRETATION OF SCATTER DIAGRAMS

- RELATIONSHIP BETWEEN VARIABLES – CORRELATION
- TYPES OF CORRELATIONS
  - POSITIVE
  - NEGATIVE
  - NONE
  - NON LINEAR

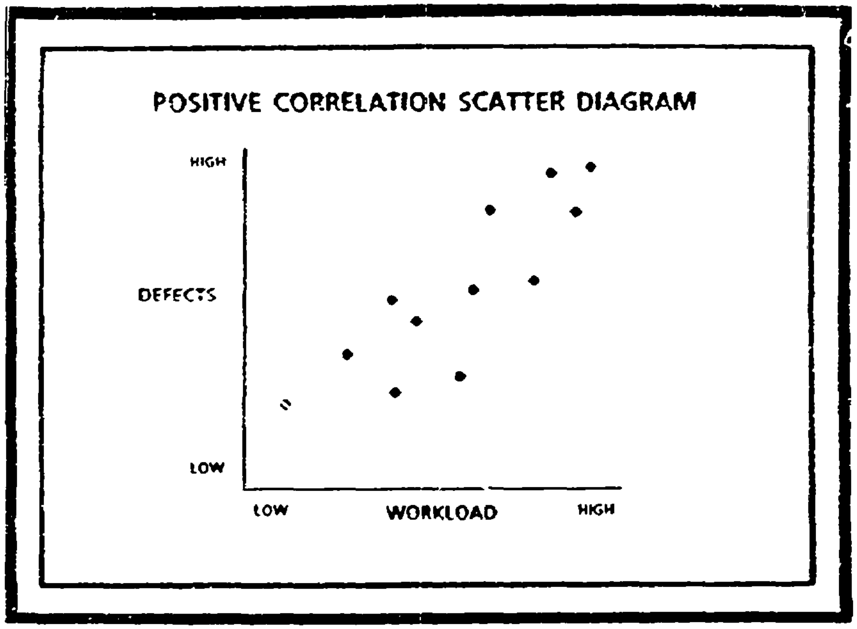
- Briefly describe the types of correlations. Use a blackboard to draw an example of each one.
- Positive -- the variables change in the same direction.
- Negative -- the variables change in opposite directions.
- None -- the variables show no discernable pattern.
- Non-linear -- the pattern is curved.

Instructor's Notes:



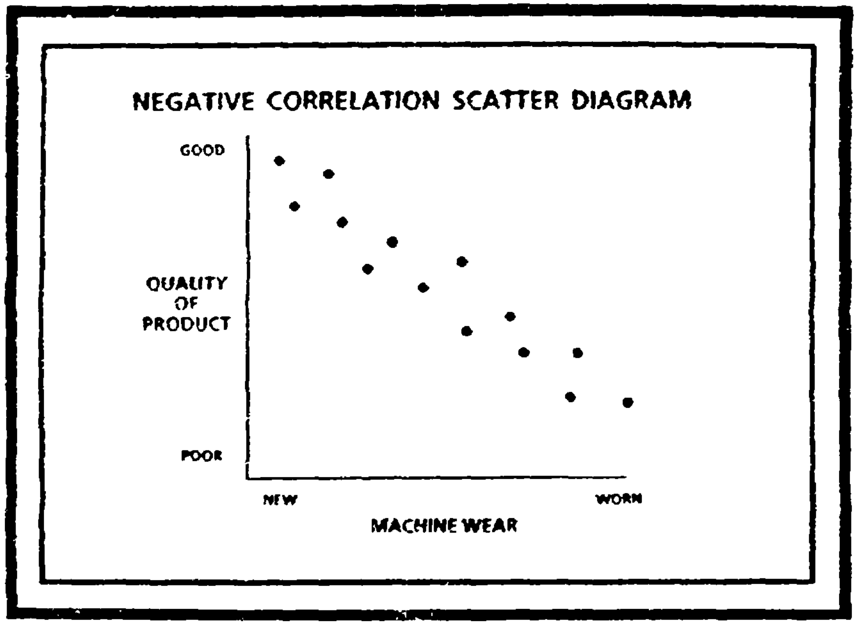
- Briefly review the parts of this scatter diagram.
- Point out the pattern associated with two variables that are positively correlated.

Instructor's Notes:



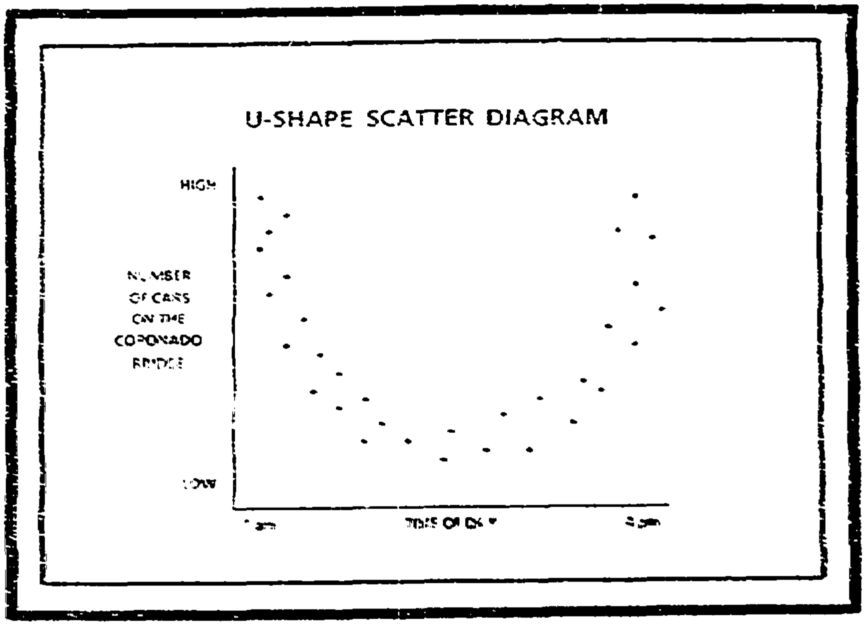
- Briefly review the parts of this scatter diagram.
- Point out the pattern associated with two variables that are positively correlated.

Instructor's Notes:



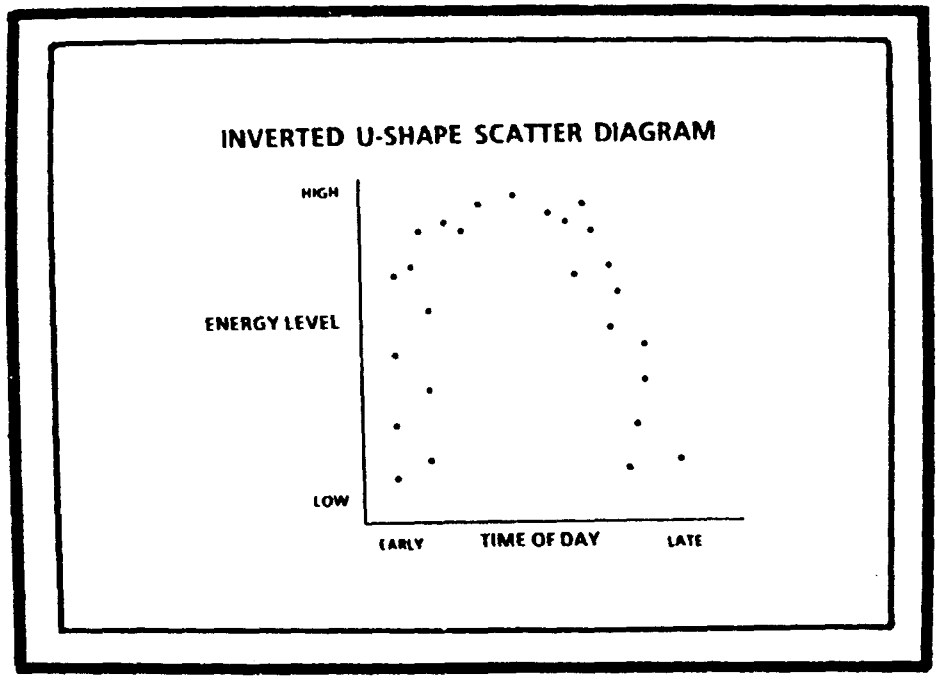
- Briefly review the parts of this scatter diagram.
- Point out the pattern associated with two variables that are negatively correlated.

Instructor's Notes:



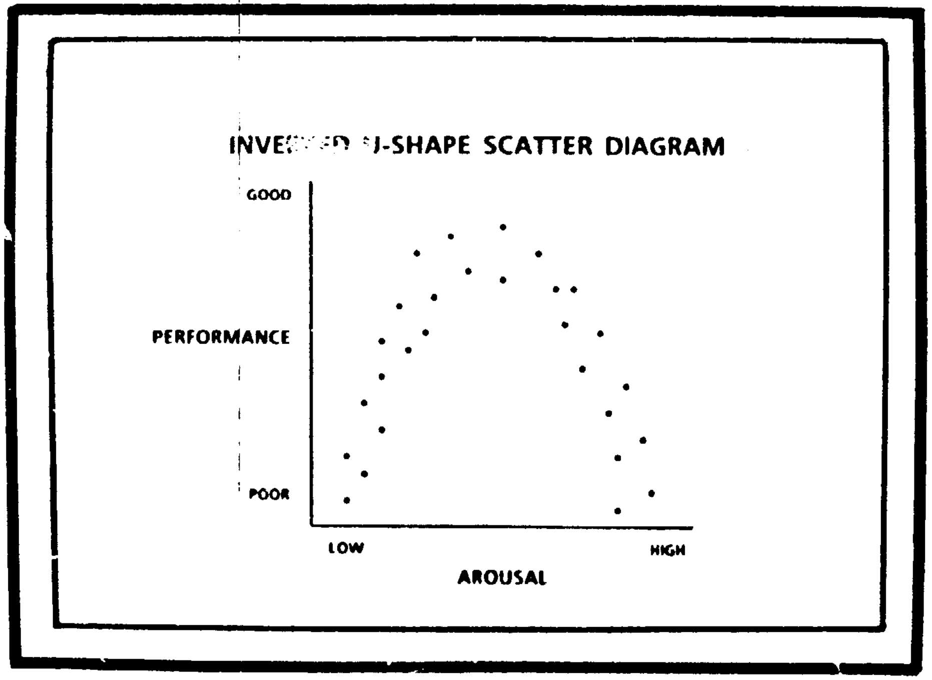
- Briefly review the parts of this scatter diagram.
- This represents a non-linear relationship.
- Describe how the relationship of the variables changes depending on the "time of day."

Instructor's Notes:



- Briefly review the parts of the scatter diagram.
- This represents a non-linear relationship.
- Describe how the relationship of the variables changes depending on the "time of day."

Instructor's Notes:



- Briefly review the parts of this scatter diagram.
- This represents a non-linear relationship.
- Describe how the relationship of the variables changes depending on "how nervous you are."

Instructor's Notes:

CAUTION ABOUT CORRELATIONS

- A CORRELATION DOES NOT MEAN CAUSATION

- Even the strongest correlation does not ensure a causal relationship.
- As an example, draw a scatter diagram representing a positive correlation between ice cream sales and violent crime, then give an alternate cause for the correlation (summer heat).
- Give a NARF-related example (e.g., defect rate and time in quarter both are correlated with workload).

Instructor's Notes:

HOW TO CONSTRUCT A SCATTER DIAGRAM

1. COLLECT SAMPLES OF DATA FROM TWO VARIABLES WHOSE RELATIONSHIP YOU WANT TO INVESTIGATE. COLLECT THESE PAIRS OF INFORMATION AT THE SAME TIME.
2. DRAW HORIZONTAL AND VERTICAL AXES AND LABEL THEM APPROPRIATELY.
3. PLOT THE PAIRS OF DATA ON THE GRAPH. IF A DATA PAIR IS REPEATED, DRAW A CIRCLE AROUND THAT DATA POINT.

- Scatter diagrams are very easy to construct.
- Collect data points from the two variables at the same time.

Instructor's Notes:

EXAMPLES OF RELATIONSHIP BETWEEN TWO VARIABLES

- RATE OF DEFECTS AND HOURS TO COMPLETE
- JOB EXPERIENCE AND ERROR RATE
- CLOSENESS OF SUPERVISION AND PERFORMANCE
- SICK LEAVE AND TENURE

- Briefly review these examples. Relate them to the NARF when possible.
- Give other relevant examples (e.g., what is the relationship between quality and productivity? Deming says as quality improves, so does productivity.).
- Construct a scatter diagram using "real" data gathered from class members (e.g., the time to cross the Coronado Bridge plotted against the time of day).

Instructor's Notes:

SUMMARY OF SCATTER DIAGRAMS

- DEFINITION
- USE
- INTERPRETATION
- CAUTION
- CONSTRUCTION

- Use this slide to review the major points of Session 7.
- At this point you may wish to preview the Session 7 lab exercise.

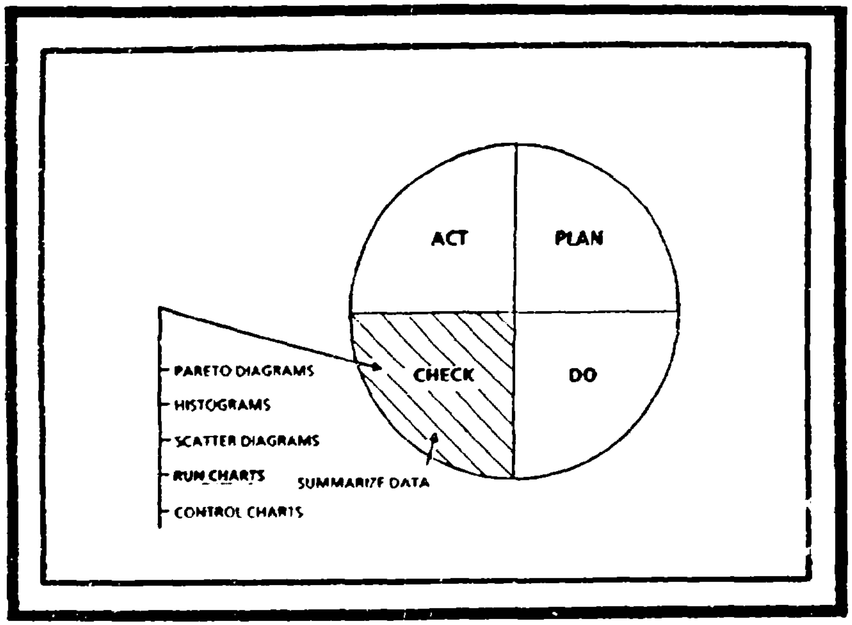
Instructor's Notes:

SESSION 8: RUN CHARTS

RUN CHARTS

- Review the Session 7 lab exercise.
- Introduce Session 8, run charts.

Instructor's Notes:



- Review the PDCA cycle.
- Run charts are most frequently used in the Check phase of the cycle.

Instructor's Notes:

WHAT WE'LL COVER IN SESSION 8

RUN CHARTS

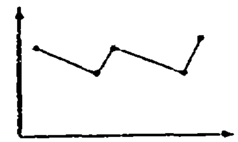
- DEFINITION
- USES
- TERMS
- MEASURES
- CONSTRUCTION
- EXAMPLES

- Use this slide to preview Session 8.
- Run charts can use different measurement scales (i.e., frequency, percentage, and range).

Instructor's Notes:

DEFINITION OF A RUN CHART

- A RUN CHART IS A LINE GRAPH THAT SHOWS DATA PLOTTED OVER TIME



- Use this slide to briefly review the form and *definition of a run chart.*
- Run charts, unlike the graphs presented in previous classes, are more dynamic. They compare one or more samples over a period of time.
- Run charts do not provide as much detailed information on each sample as do Paretos or histograms.

Instructor's Notes:

USES OF RUN CHARTS

- SUMMARIZE LARGE AMOUNTS OF DATA
- IDENTIFY PATTERNS OF PERFORMANCE
- SHOW VARIATION OF PROCESS PERFORMANCE
- COMPARE SEVERAL GROUPS
- SHOW EFFECT OF CORRECTIVE ACTION

- Draw examples of the last two points on a blackboard and briefly discuss them.

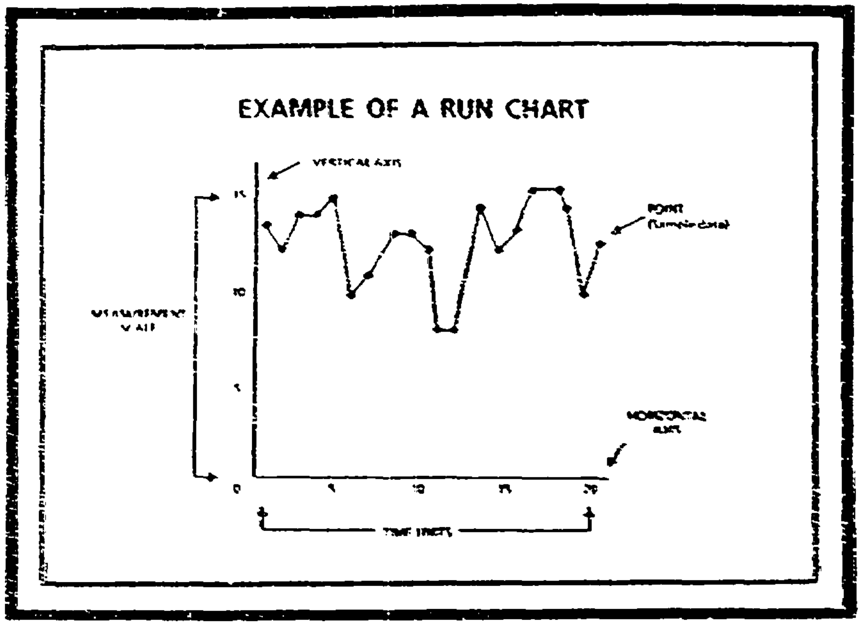
Instructor's Notes:

TERMS ASSOCIATED WITH RUN CHARTS

- POINT – REPRESENTS THE PERFORMANCE OF A SAMPLE AT A SPECIFIC TIME
- HORIZONTAL AXIS – REPRESENTS THE SAMPLING SCHEDULE
- VERTICAL AXIS – REPRESENTS THE MEASUREMENT SCALE FOR PROCESS OR OUTPUT PERFORMANCE

- Give NARF-related examples of time units (e.g., quarters) and measurement scales (e.g., number of defects).

Instructor's Notes:



- Give and ask for examples of NARF measures that could be used in a run chart.
- Run charts should include information that describes the sampling schedule and sample size.
- Sample sizes should be consistent from one sample to another to simplify the interpretation of run chart patterns.

Instructor's Notes:

MEASURES USED IN RUN CHARTS

- FREQUENCY — COUNT OF SAMPLE UNITS
- PERCENTAGE — (SUBSET OF A SAMPLE ÷ TOTAL SAMPLE SIZE) x 100
- RANGE — LARGEST VALUE – SMALLEST VALUE IN A SAMPLE
- MEAN — THE SUM OF SAMPLE MEASURES ÷ NUMBER OF MEASURES TAKEN

- Give examples of each measure on a blackboard.
- Write down the following sample and have the class work out each measure. 1, 1, 12, 9, 6, 2, 6, 12, 8, and 2.
- Tell students that they will have practice using each measure during the lab exercise.

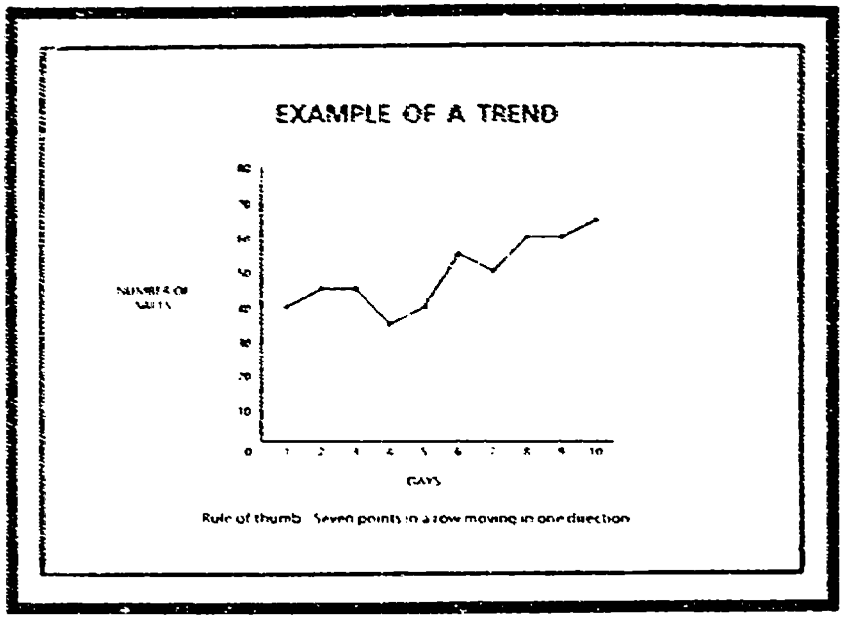
Instructor's Notes:

SUGGESTIONS FOR THE USE AND CONSTRUCTION OF RUN CHARTS

1. DETERMINE THE QUESTION YOU WANT ANSWERED
2. DEFINE PROCESS FACTORS TO BE MEASURED
3. DETERMINE SAMPLING SCHEDULE
4. OBTAIN SAMPLE
5. CALCULATE APPROPRIATE MEASURE
6. CONSTRUCT RUN CHART
7. INTERPRET PATTERN
8. RECOMMEND ACTIONS BASED ON FINDINGS

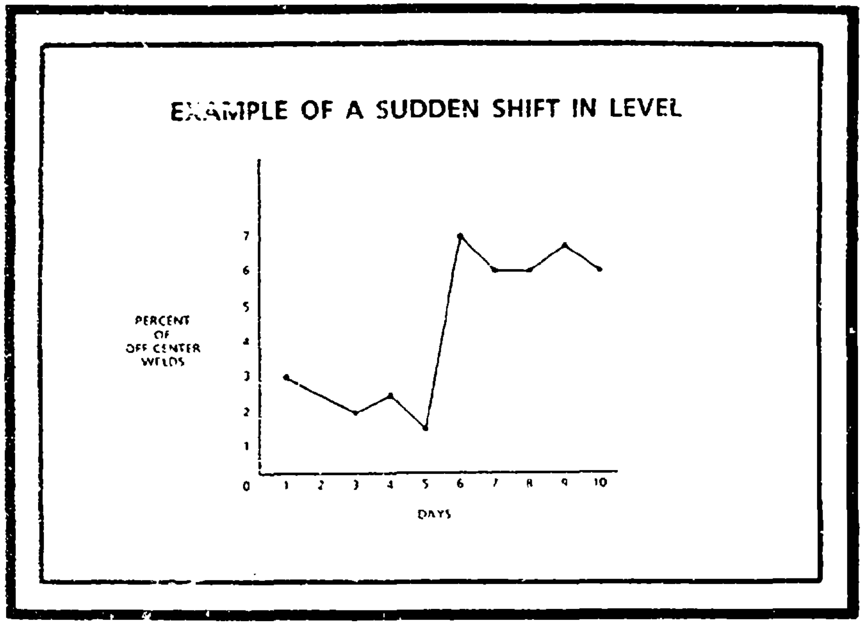
- Point three: Mention that the sampling schedule should represent the production or process schedule (e.g., if the process takes an hour to complete, then samples should be taken on an hourly as opposed to a weekly or monthly schedule).
- Point six: Mention the "three-quarter rule" for achieving consistency and accuracy in the construction of graphs. The "three-quarter rule" states that the vertical axis should be 3/4 the length of the horizontal axis.
- Point out that the list reflects all four activities of the PDCA cycle.

Instructor's Notes:



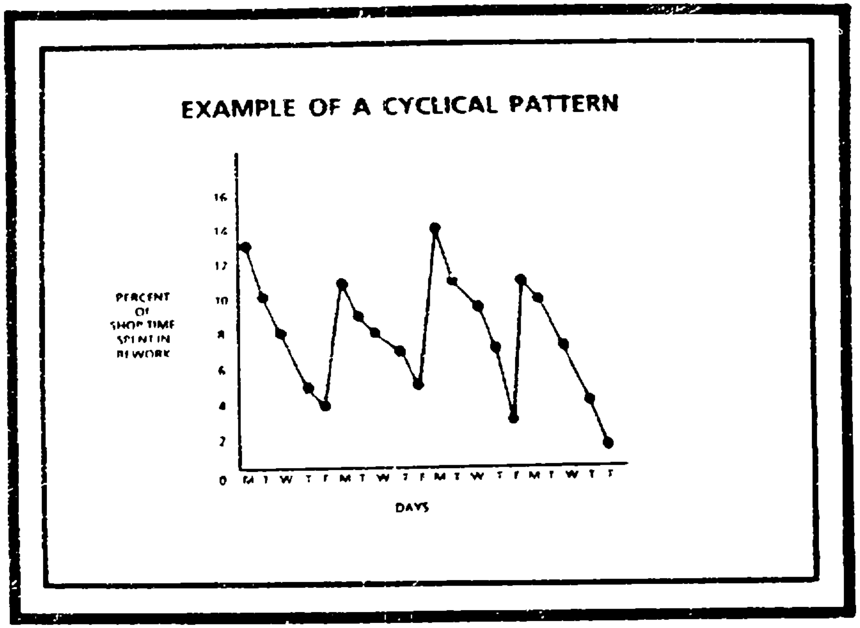
- The trend in this example starts on day 4 and moves upward.
- Ask for possible reasons for this trend.
- One interpretation of this trend is a mark-down in prices leading to an increase in sales.

Instructor's Notes:



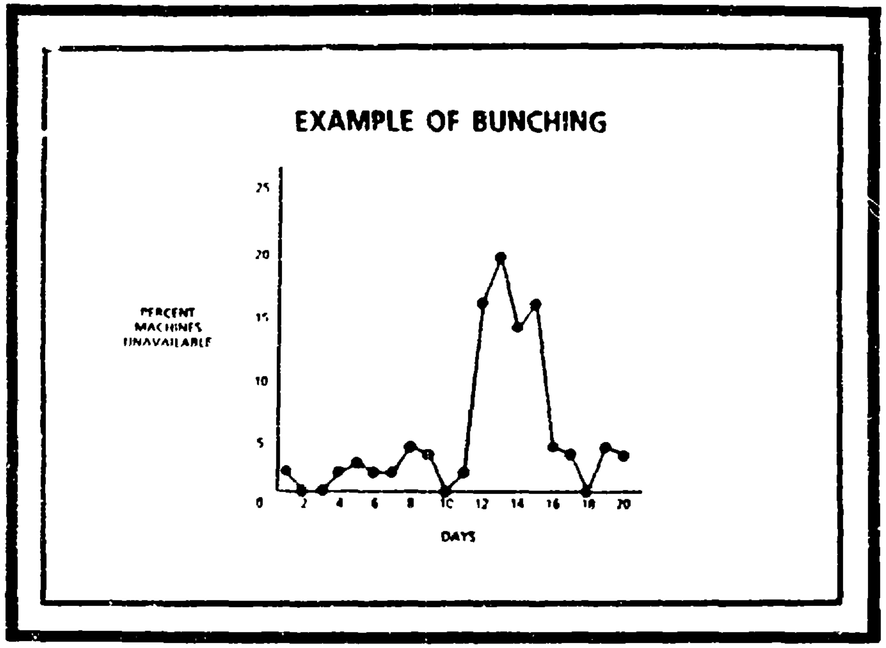
- Before and after the shift (day 5 to day 6) the performance seems to be stable.
- Ask for possible reasons for the shift.
- One interpretation of this pattern is that an outside factor has affected the entire welding process (e.g., the welding supplies just received from a vendor proved to be defective).

Instructor's Notes:



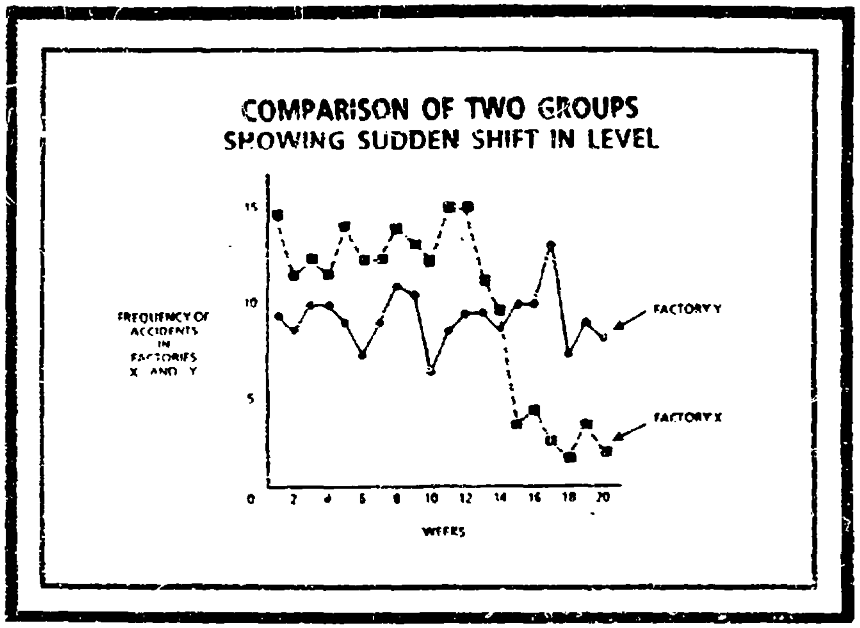
- Point out the repeating pattern.
- Ask for possible reasons for this cyclical pattern.
- Could this pattern be caused by changes in:
  - Workers (manpower)?
  - Machines?
  - Methods?
  - Material?

Instructor's Notes:



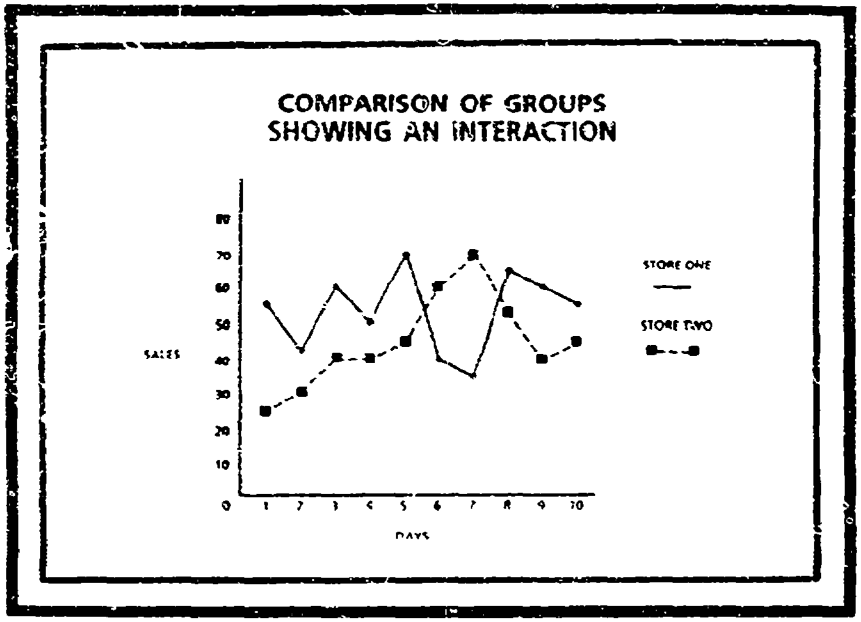
- This pattern indicates a special event that occurred for a short period of time.
- Ask the class for possible reasons for this bunching.
- One interpretation is that there was scheduled maintenance during that time period.

Instructor's Notes:



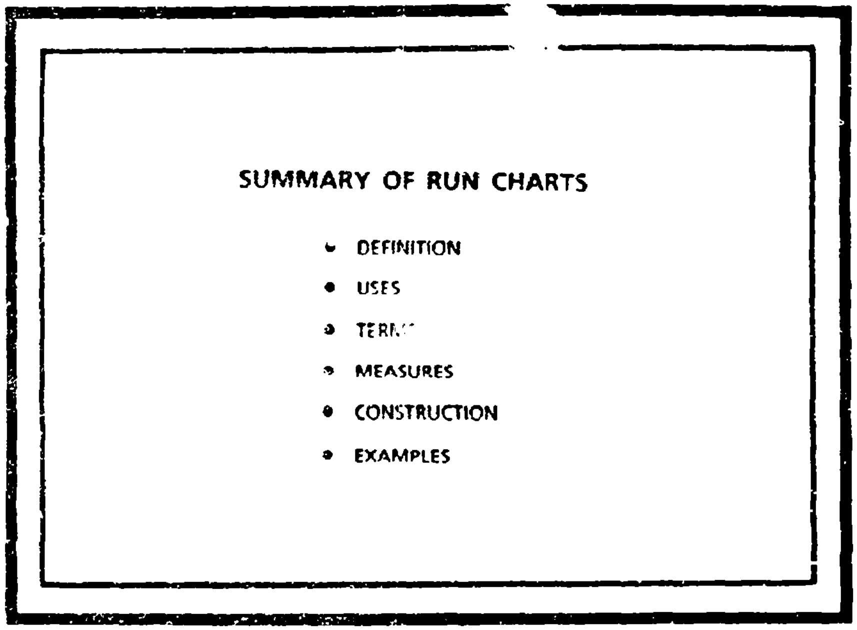
- Explain why it is important that the two groups be as similar as possible when making comparisons.
- Ask for possible reasons for the sudden shift in the accident level of factory X.

Instructor's Notes:



- On a run chart, an interaction occurs when the lines representing two or more samples cross each other.
- Note that a scatter diagram of the interaction (points 5, 6, and 7) would show a negative correlation.
- Ask for possible interpretations of the interaction.
- One interpretation is that Store Two ran a sale that took customers away from Store One.

Instructor's Notes:



- Use the summary slide to review the major points of Session 8.
- At this point you may wish to preview the Session 8 lab exercise.

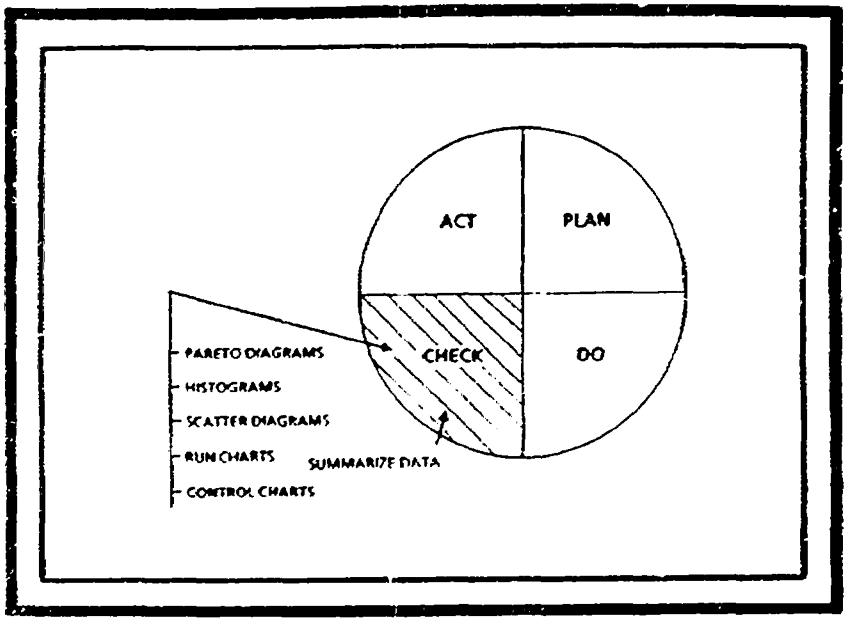
Instructor's Notes:

SESSION 9: CONTROL CHARTS

CONTROL CHARTS

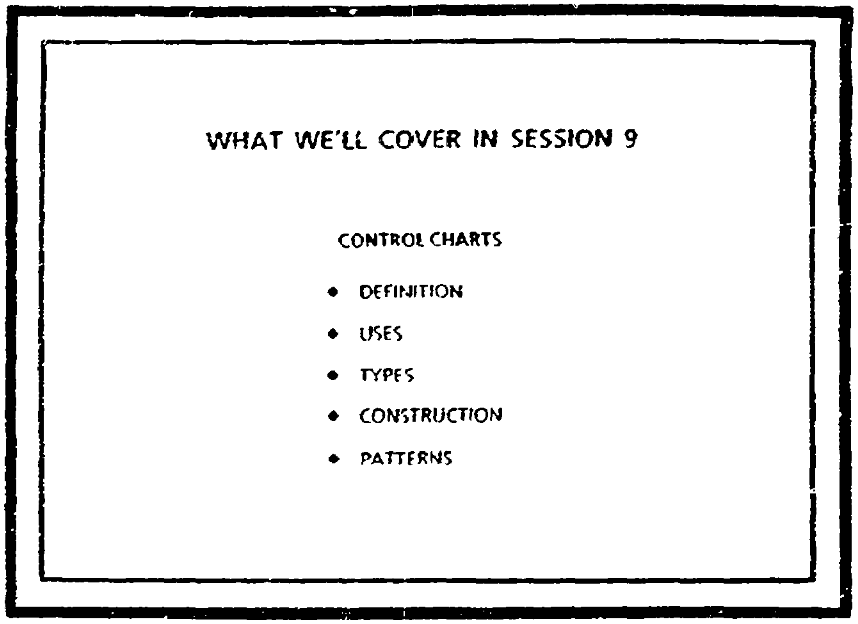
- Review the Session 8 lab exercise.
- Introduce Session 9.
- Point out that this presentation is intended to be an overview of control charting rather than an in-depth training session.

Instructor's Notes:



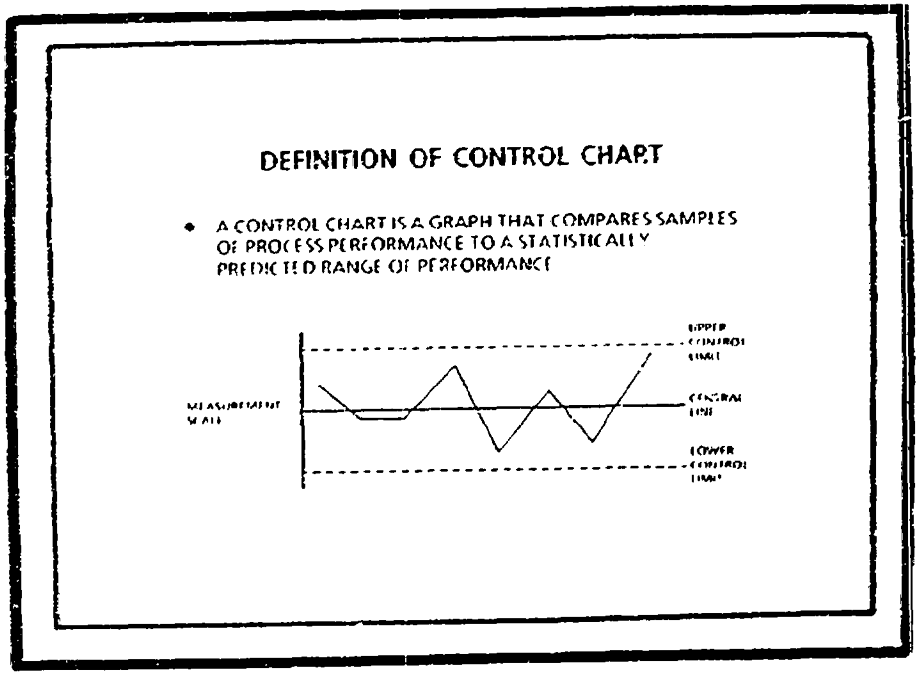
- Review the PDCA cycle.
- Control charts are most often used in the Check cycle.

Instructor's Notes:



- Use this slide to preview Session 9.
- Point three: There are different ways to compute control charts, depending on the data used.

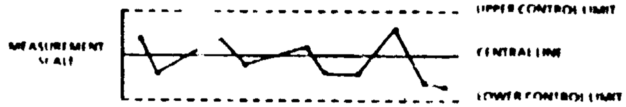
Instructor's Notes:



- Use this slide to briefly review the form and definition of a control chart.
- Measurement scales for control charts include means, proportion of defects, and number of defects.

Instructor's Notes:

ELEMENTS OF A CONTROL CHART



- MEASUREMENT SCALE – INFORMATION ON SOME IDENTIFIED PROCESS OUTPUT OR CHARACTERISTIC
- CONTROL LINES
  - UPPER CONTROL LIMIT (UCL) IS THE HIGHEST VALUE A SAMPLE SUBGROUP IS ESTIMATED TO REACH
  - CENTRAL LINE (CL) IS THE AVERAGE VALUE OF THE OVERALL SAMPLE
  - LOWER CONTROL LIMIT (LCL) IS THE LOWEST VALUE A SAMPLE SUBGROUP IS ESTIMATED TO REACH
  - NOT THE SAME AS SPECIFICATION LIMITS

- Give an example of a NARF process output or characteristic.
- Emphasize that control limits are based on the samples collected and are not the same as specification limits.
- Specification limits describe the accepted dimensions of each product.
- Control chart limits help to describe the expected performance of the process.

Instructor's Notes:

USES OF CONTROL CHARTS

- PROVIDE A DESCRIPTION OF PROCESS PERFORMANCE IN A CONCISE, TIMELY FORMAT
- EVALUATE THE STABILITY OF A PROCESS
- ASSIST IN THE DIAGNOSIS OF PROCESS PROBLEMS
  - THIS IS KNOWN AS PROCESS ANALYSIS
- ASSESS THE EFFECTS OF PROCESS IMPROVEMENT ACTIONS
  - THIS IS KNOWN AS PROCESS CONTROL

- Explain the different ways control charts can be used with NARF-related examples.

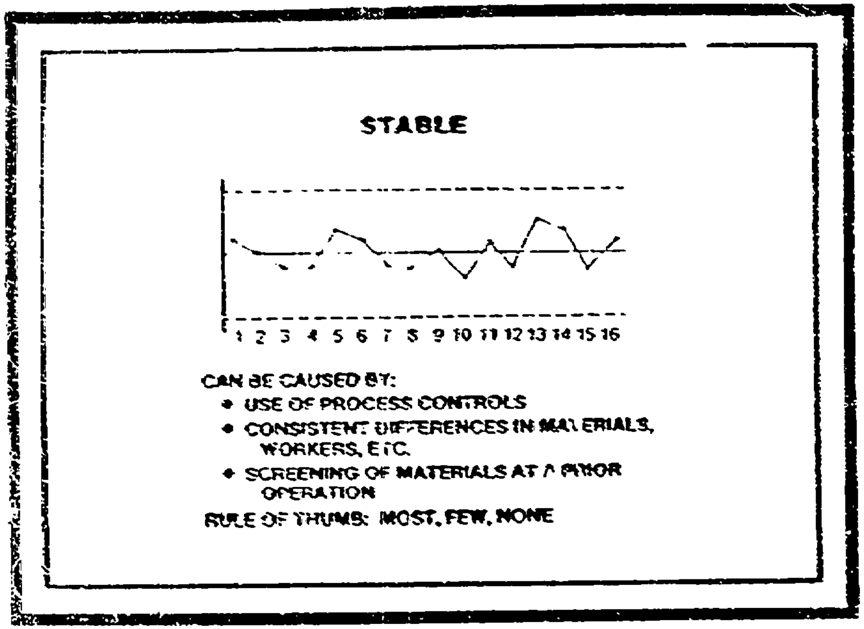
Instructor's Notes:

TYPES OF CONTROL CHARTS

- X – (X BAR) SHOWS AVERAGE OUTPUTS OF A PROCESS
- R – SHOWS THE UNIFORMITY OF A PROCESS
- P_N – SHOWS THE NUMBER OF DEFECTIVE PRODUCTS FOR SAMPLE SUBGROUPS OF EQUAL SIZES
- P – SHOWS THE FRACTION OF DEFECTIVE PRODUCTS FOR SAMPLES OF UNEQUAL SIZES
- C – SHOWS THE AVERAGE NUMBER OF DEFECTS WITHIN EACH PRODUCT FOR SAMPLE SUBGROUPS OF EQUAL SIZES
- U – SHOWS THE AVERAGE NUMBER OF DEFECTS WITHIN EACH PRODUCT FOR SAMPLE SUBGROUPS OF UNEQUAL SIZES

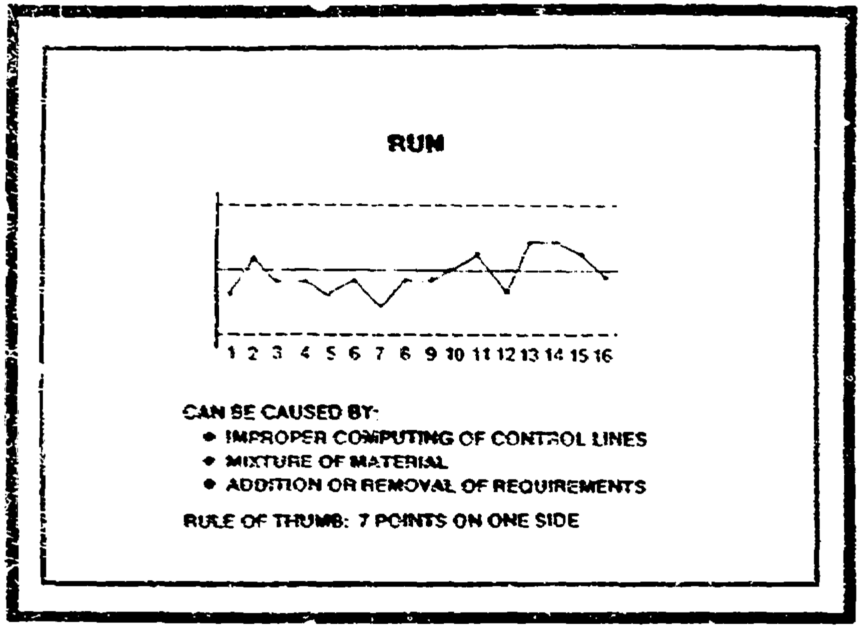
- X-bar and range charts are used together. Both use continuous data.
- Review the difference between discrete and continuous data.
- The type of information available determines the type of chart used.

Instructor's Notes:



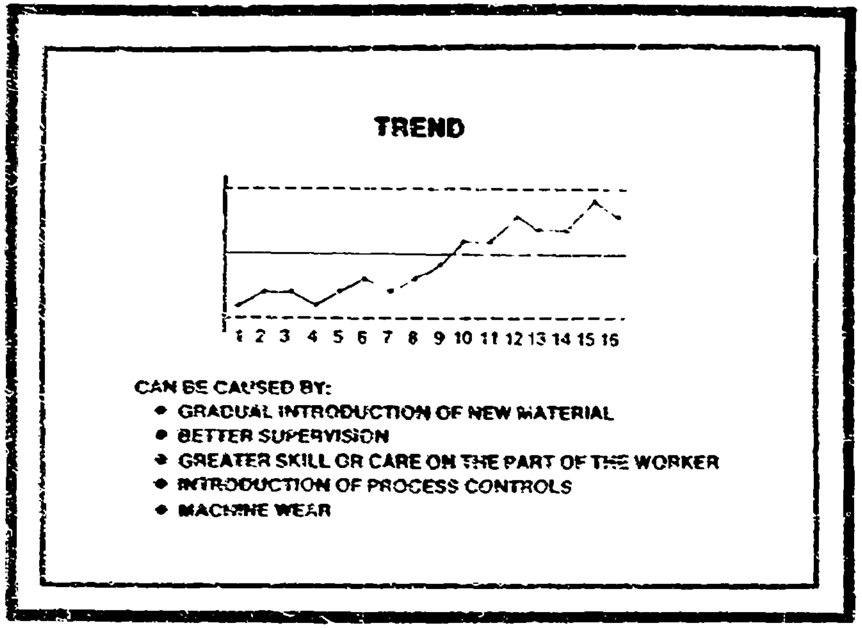
- Briefly describe the chart
- Rule of thumb.
  - "Most" points are near the center line.
  - "Few" points fall away from the center line and approach the upper and lower control limits.
  - "None" of the points go beyond the upper and lower limits.
- Point out again that a "stable pattern" does not necessarily mean everything is well with the process. Examine the variability within the control limits.

Instructor's Notes:



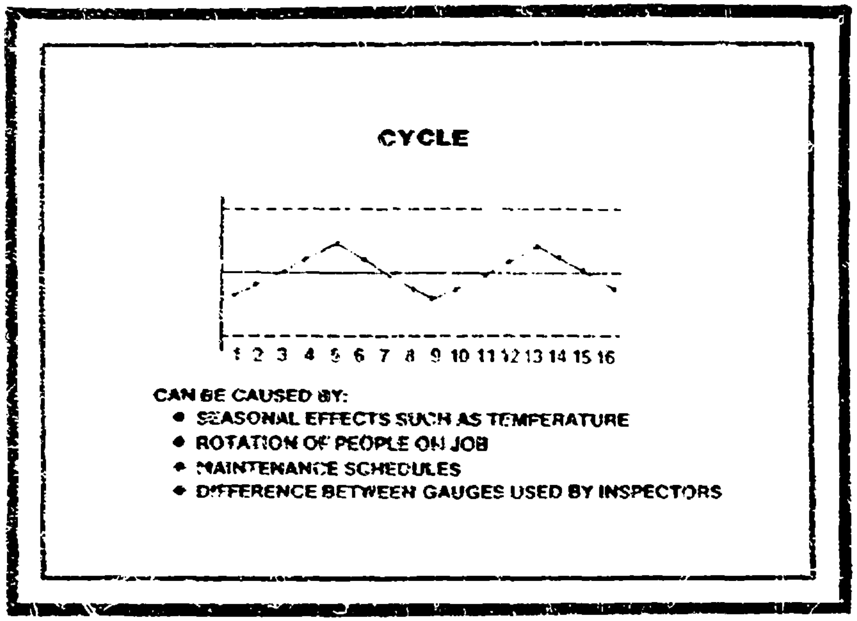
- Briefly describe the chart.
- The run occurs from point 3 to point 9.

Instructor's Notes:



- Briefly describe the chart.
- Rule of thumb - seven or more points in a row moving up or down indicate a trend.
- The trend begins at point 4.

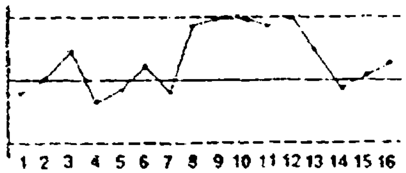
Instructor's Notes:



- Briefly describe the chart.
- Point out the recurring patterns in the chart.

Instructor's Notes:

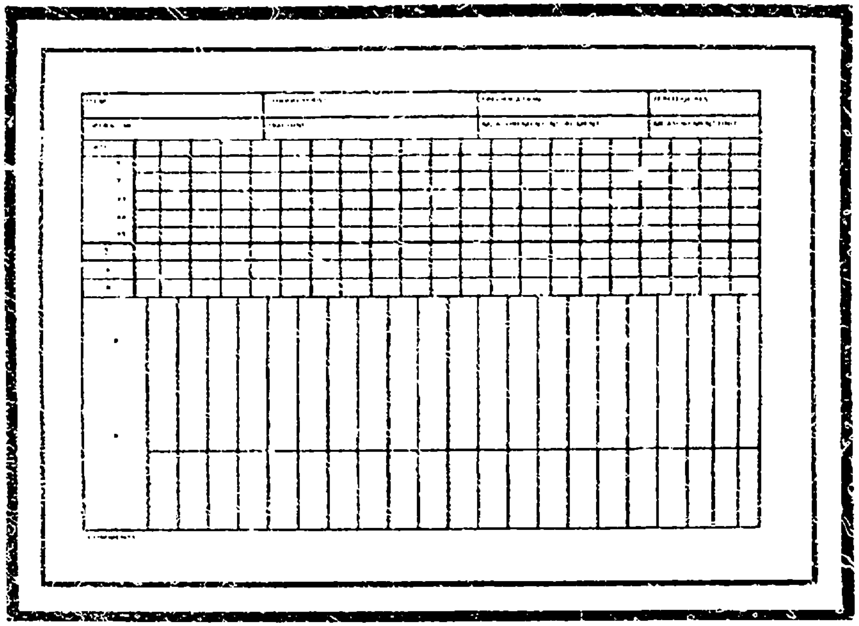
HUGGING A CONTROL LINE



CAN BE CAUSED BY:
- MIXTURE OF MATERIAL
- CHANGE IN TEST CALIBRATION
- MEASUREMENT DIFFICULTIES

- Briefly describe the chart.
- Note the several points clustering near upper control limit.
- The points can hug either an upper or lower control chart line.

Instructor's Notes:



- This slide is an example of a control chart form.
- Point out the kind of information that should be routinely recorded on a control chart.
- Define the sigma symbol as meaning the sum of a set of measures.
- Show the Wheeler tape, "A Japanese Control Chart." It gives an example of how a company used control charts to improve their process and product.
- Review the important points of the Wheeler tape.

Instructor's Notes:

GENERAL STEPS IN COMPUTING
$\bar{X}$ and R CHARTS

1. COLLECT DATA
2. COMPUTE THE MEAN FOR EACH SUBGROUP
3. COMPUTE THE RANGE FOR EACH SUBGROUP
4. COMPUTE THE OVERALL MEAN
5. COMPUTE THE AVERAGE VALUE OF THE RANGE
6. COMPUTE THE CONTROL LIMIT LINES
7. CONSTRUCT THE CONTROL CHARTS
8. PLOT OUT THE MEAN AND RANGE VALUES FOR EACH SUBGROUP

- Use the data from the run chart lab exercise to illustrate these steps.
- Have students work out steps 4-6 using the run chart data.
- Re-emphasize that a process can be in control and still produce unsatisfactory products (e.g, too much variation in the process).

Instructor's Notes:

BASIC STEPS IN USING CONTROL CHARTS

1. SELECT THE ITEMS TO BE CONTROLLED
2. DECIDE WHICH CONTROL CHART TO USE
3. MAKE A CONTROL CHART FOR PROCESS ANALYSIS
4. TAKE ACTIONS TO CORRECT PROBLEMS IDENTIFIED BY THE CONTROL CHART
5. CONSTRUCT A CONTROL CHART FOR PROCESS CONTROL
6. CONTROL THE PROCESS BY IMPROVING AND STANDARDIZING WORK METHODS AND CONDITIONS
7. RECOMPUTE THE CONTROL LINES TO REFLECT CHANGES IN OPERATING TECHNIQUES, EQUIPMENT, ETC.

- Note that these steps follow PDCA cycle.
- Review process analysis.
- Review process control.

Instructor's Notes:

SUMMARY OF CONTROL CHARTS

- DEFINITION
- USES
- TYPES
- CONSTRUCTION
- PATTERNS

- Use this slide to review the major points of Session 9.

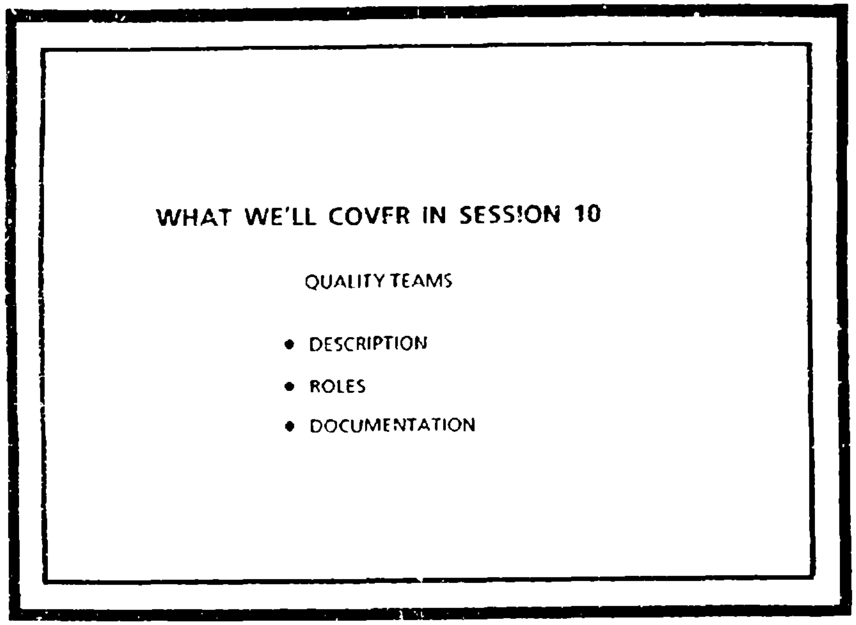
Instructor's Notes:

SESSION 10: QUALITY TEAMS

QUALITY TEAMS

- Introduce Session 10.

Instructor's Notes:



- Use this slide to preview Session 10.

- This session is divided into three sections.

  - Section one: A definition and description of the two types of quality teams here at the NARF.

  - Section two: A review of the purposes of quality teams, including the structure of the quality team meeting.

  - Section three: A discussion of how quality teams document and report their efforts in process improvement.

Instructor's Notes:

DESCRIPTION OF QUALITY TEAMS

- DEFINITION
- TYPES
- NARF QUALITY TEAMS

- Use this slide to review the topics to be discussed in the first section.

Instructor's Notes:

DEFINITION OF QUALITY TEAM

- GROUP OF INDIVIDUALS
  - FROM DIFFERENT ORGANIZATIONAL FUNCTIONS
  - WITH COMMON PURPOSE

- The involvement of all groups associated with a product allows for many different viewpoints to be represented in the improvement process (the common purpose).

Instructor's Notes:

TYPES OF QUALITY TEAMS

- QUALITY MANAGEMENT BOARDS
- PROCESS TEAMS

- These represent the two types of quality teams. Although they are both concerned with the improvement of process, they deal with different aspects of this improvement.
- The next two slides will provide more details on each type.

Instructor's Notes:

QUALITY MANAGEMENT BOARDS

- COMPOSED OF MANAGERS FROM DIFFERENT WORK UNITS (INTER-DEPARTMENTAL, INTER-DIVISIONAL)
- PROVIDE GUIDANCE AND DIRECTION TO LOWER LEVEL TEAMS
- ISSUE-GENERATED LEADERSHIP

- In general, quality management boards (QMBs) are not directly involved in any one project.

Instructor's Notes:

PROCESS TEAMS

- COMPOSED OF EXPERIENCED AND KNOWLEDGEABLE PERSONNEL
- ISSUE SPECIFIC
- WHEN ISSUE RESOLVED, TEAM DISBANDED

- Remind the class that before the process team disbands, they must make recommendations that assure the continuous improvement of that process. These recommendations may take the form of a newly focused process team, continual monitoring through control charts, monthly checks on the status of team recommendations, etc.

Instructor's Notes:

PROCESS TEAM ROLES

- PURPOSE
- ROLES WITHIN THE TEAM
- MEETING REQUIREMENTS

- Use this slide to introduce the topics to be discussed in the second section.

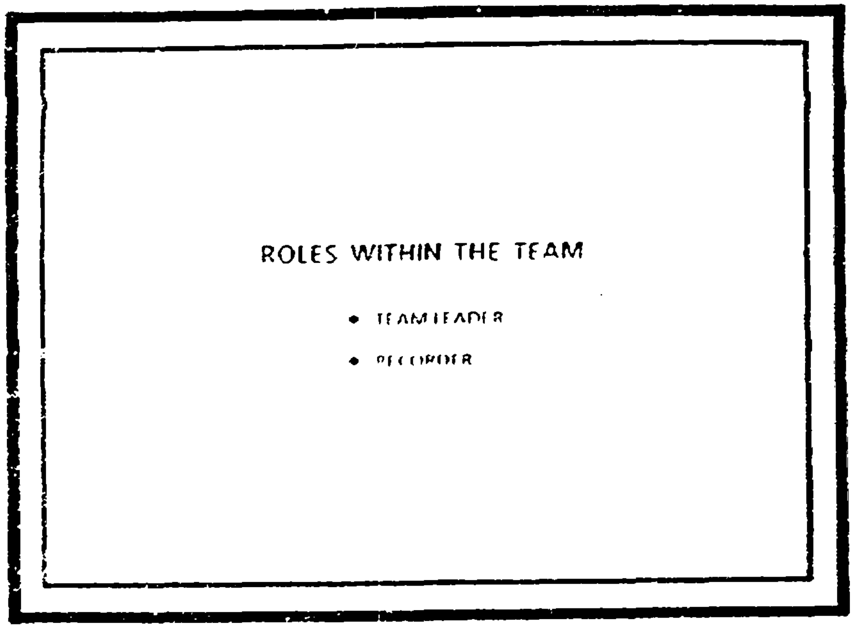
Instructor's Notes:

PURPOSES OF THE PROCESS TEAM

- INCREASE COMMUNICATION AND COOPERATION
- DISCUSS PROCESS AND PROBLEMS WITHOUT "FINGER POINTING"
- OBTAIN A BROAD PICTURE OF HOW WORK UNITS AND PROCESSES INTERRELATE THROUGH DATA COLLECTION
- IMPROVE PROCESSES CONTINUOUSLY

- Process improvement is carried out, documented, and evaluated by process.
- By working outside of the traditional structure of shops and management, the teams help to reduce fear and increase open communication among members.

Instructor's Notes:



- Every team must fill these offices.
- The team leader is responsible for the agenda and for keeping the meeting on track.
- The recorder documents any previous or proposed actions in the minutes.

Instructor's Notes:

MEETING REQUIREMENTS

- LOGISTICS
- AGENDA
- ATTENDANCE

- Attention to these three components can make the difference between a productive and a non-productive meeting.
- Each of these components will be discussed in detail in the following slides.

Instructor's Notes:

LOGISTICS

- LOCATION
- TIME
- GROUP SIZE
- MATERIALS

- Attention to logistics assures that the meeting will be conducted in a room appropriate for the size and purpose of the group.
- Be sure that the team members are aware of the meeting time and place in time to make arrangements to attend.
- A group of 10 to 12 is about the maximum size for effective communications during group problem-solving meetings.
- Suggest that a chalkboard or flipchart be available at each meeting. Issues and ideas raised during the meeting can then be posted to aid group discussions.

Instructor's Notes:

AGENDA

- START ON TIME
- OUTLINE TOPICS AND GOALS
- REVIEW STATUS AND PROGRESS OF PAST ACTION ITEMS
- REVIEW DATA OBTAINED BY TEAM MEMBERS
- DEVELOP AND ASSIGN NEW ACTION ITEMS
- INFORM TEAM OF TIME, PLACE, AND TOPICS OF NEXT MEETING
- END ON TIME

- An agenda adds order to the team meeting.
- An agenda provides the team leader with a stucture within which ongoing and new action items may be discussed. It helps to remind him or her which topics need to be covered before the meeting is adjourned.

Instructor's Notes:

ATTENDANCE

- BE ON TIME
  - IF LATE/ABSENT, NOTIFY TEAM LEADER
- KEEP ATTENDANCE RECORDS OF ALL MEETINGS
- IF SUBSTITUTE ALLOWED, SHOULD HAVE FULL DECISION MAKING POWER
- IF TEAM LEADER LATE/ABSENT, ALTERNATE SHOULD CONDUCT MEETING

- Poor attendance and late attendees can kill the momentum of the any team meeting.
- Do not cancel a meeting because the team leader cannot be there.
- Make it clear to team members that they are on the team because their input is valued and needed.
- Attendance records should be kept of all meetings.
- Causes of inadequate attendance should be identified and dealt with as soon as possible.

Instructor's Notes:

DOCUMENTATION

- MEETING MINUTES
- PROGRESS REPORTS

- This section covers the two types of documentation required of teams.
- Meeting minutes cover the on-going activities of the teams from meeting to meeting.
- Progress reports are used to summarize the team's accomplishments along the PDCA.

Instructor's Notes:

USES OF MEETING MINUTES

- UPDATE MEMBERS WHO MISSED MEETING
- REMIND TEAM MEMBERS OF AC[illegible]N ITEMS
- [illegible]DATE OTHER QUALITY TEAMS OF PROGRESS
- SU[illegible]ST DISCUSSION TOPICS FOR NEXT MEETING

- **Minutes are kept by the team recorder and are read at each team meeting.**
- **The team minutes consist of statements that summarize the major findings and results of discussion topics for each meeting.**

Instructor's Notes:

KEY ELEMENTS OF MEETING MINUTES

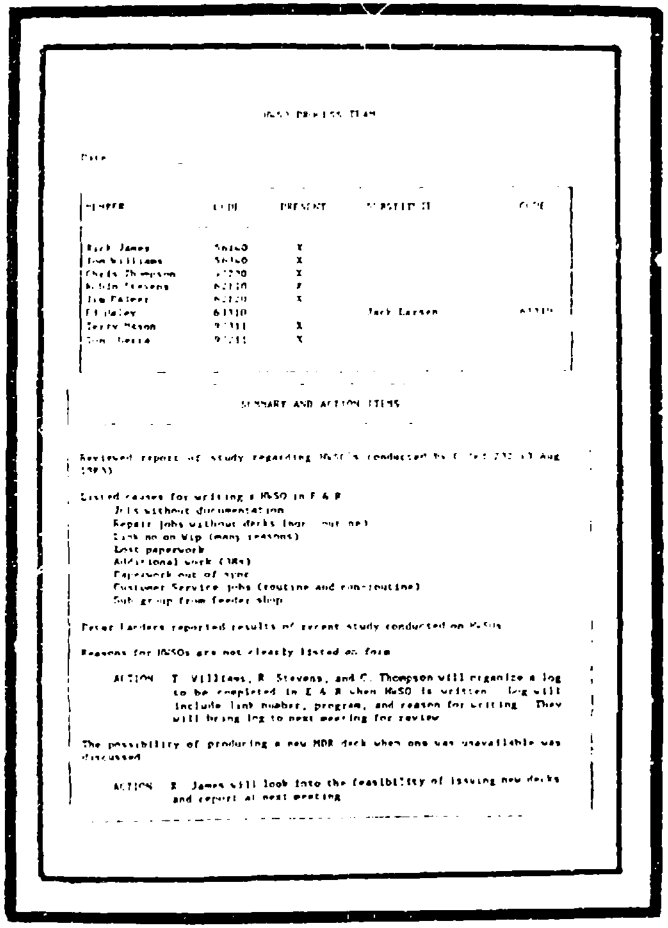
- LIST OF ATTENDEES
- SUMMARY OF DISCUSSION
- LIST OF ACTION ITEMS

  RESPONSIBLE PERSON
  METHOD OF DATA COLLECTION
  PLANNED COMPLETION DATE

- DATA PRESENTED WITH BASIC GRAPHIC METHODS
- SUMMARY OF ACTIVITIES AND PROGRESS

- Hand out a blank copy of the minutes form to each class member.
- Discuss the elements represented on this form.

Instructor's Notes:



PROCESS TEAM

Date

MEMBER	CODE	PRESENT	SUBSTITUTE	CODE
Rick James	56160	X		
Tom Williams	56160	X		
Chris Thompson	[illegible]	X		
Robin Stevens	62130	X		
Jim Palmer	62120	X		
Ed Daley	61310		Jack Larsen	[illegible]
Terry Mason	[illegible]	X		
Tom [illegible]	[illegible]	X		

SUMMARY AND ACTION ITEMS

Reviewed report of study regarding [illegible] conducted by [illegible] Aug [illegible])

Listed causes for writing a MSO in E & R
- Jobs without documentation
- Repair jobs without decks (nor [illegible])
- Link no on Wip (many reasons)
- Lost paperwork
- Additional work (ORs)
- Paperwork out of sync
- Customer Service jobs (routine and non-routine)
- Sub group from feeder shop

Peter Larders reported results of recent study conducted on MSOs

Reasons for MSOs are not clearly listed on form

ACTION T. Williams, R. Stevens, and C. Thompson will organize a log to be completed in E & R when MSO is written. Log will include link number, program, and reason for writing. They will bring log to next meeting for review

The possibility of producing a new MDR deck when one was unavailable was discussed

ACTION R. James will look into the feasibility of issuing new decks and report at next meeting

- This is an example of a minutes form completed at a NARF process team meeting.
- Discuss the items that have been recorded on the form.
- Emphasize the need to specify actions to be taken, by whom, and by what time.

Instructor's Notes:

USES OF PROGRESS REPORTS

- UPDATE OTHER TEAMS ON STATUS OF PROJECTS
- SUMMARIZE FINDINGS OF PROCESS TEAMS FOR SUBMISSION TO DIVISION
- DOCUMENT ACTIONS, DECISIONS, AND RECOMMENDATIONS OF TEAMS

- **Discuss the uses of progress reports using the blank as an outline.**

Instructor's Notes:

KEY ELEMENTS OF PROGRESS REPORTS

- OBJECTIVE
- ANALYSIS
- PLAN OF ACTION
- PERSONS CONTACTED
- INFORMATION OBTAINED
- ACTIONS TAKEN
- RECOMMENDATIONS
- POTENTIAL PROBLEMS

- Hand out the sample progress report form (blank).
- Every progress report may be divided into several components. There are eight major components. Some or all may apply to a specific project.
- The next eight slides will examine the progress report components individually.

Instructor's Notes:

OBJECTIVE

- CLEARLY STATES THE ISSUE TO BE ADDRESSED BY TEAM
- DEFINES ISSUE SO SCOPE IS APPROPRIATE TO TEAM TO WHICH IT IS ASSIGNED

- A clearly stated objective allows the reader to understand the purpose of the team's activities.
- Objective should be achievable by the team. They should have the needed knowledge, resources, and authority to address the process they've been assigned to work on.

Instructor's Notes:

ANALYSIS

- DESCRIBES FACTS RELEVANT TO THE ISSUE
- PROVIDES THE BACKGROUND AND REASONING THAT LEAD TO DATA COLLECTION
- SUMMARIZES THE PLAN PHASE OF THE PDCA CYCLE

- The analysis conveys the background information that leads to the formation of a process team to investigate this issue. This section summarizes the rationale or justification for investigating the issue.

Instructor's Notes:

PLAN OF ACTION

- DESCRIBES ACTIONS TO BE TAKEN
- PROVIDES AN ESTIMATED COMPLETION DATE
- SUMMARIZES THE DO PHASE OF THE PDCA CYCLE

- The plan of action section summarizes the major areas of investigation including the techniques used by the project team.

Instructor's Notes:

PERSONS CONTACTED

- LISTS PEOPLE CONTACTED IN THE ORGANIZATION NOT ON THE TEAM
- LISTS PEOPLE CONTACTED OUTSIDE THE ORGANIZATION
- PROVIDES INFORMATION IF FUTURE CONTACT IS DESIRED

- These lists document outside contacts made by the process team. It can prove useful if future contact is desired.

Instructor's Notes:

INFORMATION OBTAINED

- DESCRIBES DATA COLLECTED
- PROVIDES ACTUAL COMPLETION DATES
- PRESENTS DATA USING THE BASIC GRAPHIC TECHNIQUES
- SUMMARIZES THE CHECK PHASE OF THE PDCA CYCLE

- The section on information obtained contains the summary of data collection and interpretation. It summarizes the check phase of this PDCA cycle.
- Graphic presentations of the data can be attached to the written report.

Instructor's Notes:

ACTIONS TAKEN

- PRESENTS TEAM'S ACTIONS
- DESCRIBES NEW PRACTICES/PROCEDURES/POLICIES
- SUMMARIZES THE ACT PHASE OF THE PDCA CYCLE

- The section on actions taken describes the actions that the project team took at its level to improve the process, based on the information collected.

Instructor's Notes:

RECOMMENDATIONS

- PRESENTS TEAM'S RECOMMENDATIONS FOR FURTHER ACTION BY
  - PROCESS TEAMS
  - DIVISION QUALITY MANAGEMENT BOARD
- CAN SUGGEST THE NEED FOR ANOTHER PDCA CYCLE AND/OR CONTINUED PROCESS MONITORING

- The recommendation section allows the process team members to use the expertise they have developed while working through the PDCA cycle to make suggestions for further process improvement.
- This section should include the team's recommendations for issues to be considered by the Division Quality Management Board.

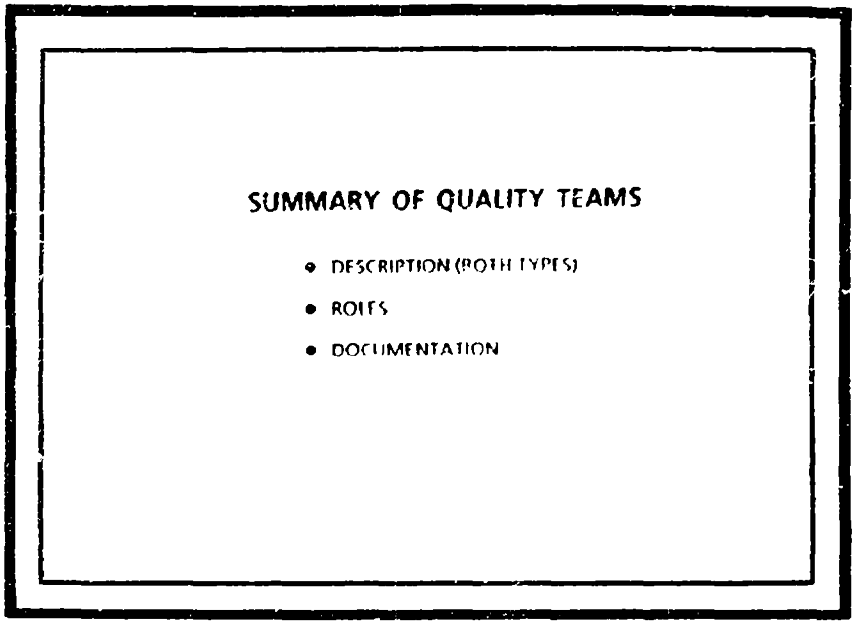
Instructor's Notes:

POTENTIAL PROBLEMS

- SUMMARIZES PROBLEMS RELEVANT TO TEAM'S INVESTIGATION
- LISTS ANTICIPATED CONSEQUENCES OF DATA COLLECTION
- SUMMARIZES PROBLEMS RELEVANT TO IMPLEMENTING RECOMMENDATIONS

- The potential problems section summarizes any barriers to process improvement or change and anticipates any future difficulties in carrying out recommendations.

Instructor's Notes:



- Use this slide to summarize the main points of Session 10.

Instructor's Notes:

LAB SESSION 1: INTRODUCTION AND OVERVIEW

Lab Session 1: Introduction and Overview

The purpose of the Session One lab is to give the students some experiences that will allow them to compare individual and group problem-solving methods. This exercise also points out the advantages of involving individuals with various backgrounds in a structured group problem-solving process. To fulfill this purpose, a group technique, "Lost at sea: A consensus task," is used.

The following pages present the rationale, suggested techniques, and materials for using this group process exercise. These pages are excerpted from Nemiroff, P. M., & Pasmore, W. A. (1975), The 1975 annual handbook for group facilitators, La Jolla, CA: University Associates Publishers, Inc.

Lab 1-2

140. LOST AT SEA: A CONSENSUS-SEEKING TASK

Goals

I. To teach the effectiveness of consensus-seeking behavior in task groups through comparative experiences with both individual decision-making and group decision-making.

II. To explore the concept of synergy in reference to the outcomes of group decision-making.

Group Size

Five to twelve participants. Several groups may be directed simultaneously. (Synergistic outcomes are more likely to be achieved by smaller groups, e.g., five to seven participants.)

Time Required

Approximately one hour.

Materials

I. Pencils.

II. Two copies of the Lost at Sea Individual Worksheet for each participant.

III. A copy of the Lost at Sea Group Worksheet for each subgroup.

IV. A copy of the Lost at Sea Answer and Rationale Sheet for each participant.

V. Newsprint and felt-tipped markers.

Physical Setting

Lapboards or desk chairs are best for privacy in individual work. Tables may be used, but the dynamics involved are likely to be different.

Process

I. The facilitator distributes two copies of the Lost at Sea Individual Worksheet to each participant and asks each person to complete the forms in duplicate. He explains that participants are to work independently during this phase.

II. After fifteen minutes, the facilitator collects one copy from each participant. The other copy is for the use of the group.

III. The facilitator forms subgroups and directs them to particular work areas in the room. He gives one Lost at Sea Group Worksheet to each group. The facilitator then reads the instructions to the groups, emphasizing that each member of a group should partially agree with the group choices to establish consensus, but that they are not to use such techniques as averaging, majority-rule voting, or trading. He stresses that it is desirable that effort be made to achieve success in this task.

IV. While the groups are engaged in their task, the facilitator scores the individual ranking sheets. The score is the sum of the differences between the "correct" rank for each item and its rank on the Individual Worksheet (all differences should be made positive and added). Higher scores have greater negative implications. The facilitator then totals all individual scores for each group and divides by the number of group members to obtain the average individual score for each group.

V. After thirty-five minutes, the facilitator collects the Group Worksheets and scores them as he did the Individual Worksheets, while the participants debrief their consensus-seeking. He then prepares a chart such as the one following, summarizing the statistics.

BEFORE GROUP DISCUSSION

Group	Average Individual Score	Score of Most Accurate Individual
Example	55	45
1		
2		
3		
Average for all groups		

AFTER GROUP DISCUSSION

Group	Score for Group Consensus	Gain/Loss Over Average Individual	Gain/Loss Over Most Accurate Individual	Synergy*
Example	40	+15	+5	Yes
1				
2				
3				
Average for all groups				

*Synergy is defined as the consensus score lower than the lowest individual score in the group

VI. The facilitator returns all Individual and Group Worksheets and distributes a copy of the Lost at Sea Answer and Rationale Sheet to each participant. After allowing the groups a few minutes to discuss the answers and rationale, the facilitator analyzes the statistics and explains the synergy factor.

VII. The facilitator leads a discussion of the comparative outcomes of individual rankings and group consensus rankings. Discussion questions such as the following might be suggested by the facilitator:

- What behaviors helped or hindered the consensus-seeking process?
- What patterns of decision-making occurred?
- Who were the influential members and how were they influential?
- How did the group discover and use its information resources? Were these resources fully utilized?
- What are the implications of consensus-seeking and synergistic outcomes for intact task groups such as committees and staffs of institutions?
- What consequences might such a process produce in the group's attitudes?

Variations

I. Process observers can be used to give feedback about either group behavior or individual behavior.

II. A lecturette on synergy and consensus-seeking can immediately precede the group problem-solving phase to establish a mental set toward cooperation.

III. Each participant can be given only one copy of the Lost at Sea Individual Worksheet and instructed to score his own sheet.

Similar Structured Experiences: *Vol. I:* Structured Experience 11; *Vol. II:* 30; *Vol. III:* 64, 69; '72 *Annual:* 77; *Vol. IV:* 115.

Lecturette Source: '73 *Annual:* "Synergy and Consensus-Seeking."

Submitted by Paul M. Nemiroff and William A. Pasmore.

LOST AT SEA: INDIVIDUAL WORKSHEET

Name ____________________

Group ____________________

Instructions: You are adrift on a private yacht in the South Pacific. As a consequence of a fire of unknown origin, much of the yacht and its contents have been destroyed. The yacht is now slowly sinking. Your location is unclear because of the destruction of critical navigational equipment and because you and the crew were distracted trying to bring the fire under control. Your best estimate is that you are approximately 1,000 miles south-southwest of the nearest land.

Below is a list of 15 items that are intact and undamaged after the fire. In addition to these articles, you have a serviceable rubber life raft with oars large enough to carry yourself, the crew, and all the items listed below. The total contents of all survivors' pockets are a package of cigarettes, several books of matches, and five one-dollar bills.

Your task is to rank the 15 items below in terms of their importance to your survival. Place the number 1 by the most important item, by the second most important place the number 2, and so on through number 15, the least important.

_____ Sextant

_____ Shaving mirror

_____ Five-gallon can of water

_____ Mosquito netting

_____ One case of U.S. Army C rations

_____ Maps of the Pacific Ocean

_____ Seat cushion (floatation device approved by the Coast Guard)

_____ Two-gallon can of oil-gas mixture

_____ Small transistor radio

_____ Shark repellent

_____ Twenty square feet of opaque plastic

_____ One quart of 160-proof Puerto Rican rum

_____ Fifteen feet of nylon rope

_____ Two boxes of chocolate bars

_____ Fishing kit

LOST AT SEA: GROUP WORKSHEET

Group ____________________

Instructions. This is an exercise in group decision making. Your group is to employ the group consensus method in reaching its decision. This means that the prediction for each of the 15 survival items must be agreed upon by each group member before it becomes a part of the group decision. Consensus is difficult to reach. Therefore, not every ranking will meet with everyone's complete approval. As a group, try to make each ranking one with which all group members can at least partially agree. Here are some guides to use in reaching consensus.

1. Avoid arguing for your own individual judgments. Approach the task on the basis of logic.

2. Avoid changing your mind if it is only to reach agreement and avoid conflict. Support only solutions with which you are able to agree at least somewhat.

3. Avoid "conflict-reducing" techniques such as majority vote, averaging, or trading in reaching your decision.

4. View differences of opinion as a help rather than a hindrance in decision making.

_____ Sextant

_____ Shaving mirror

_____ Five-gallon can of water

_____ Mosquito netting

_____ One case of U.S. Army C rations

_____ Maps of the Pacific Ocean

_____ Seat cushion (floatation device approved by the Coast Guard)

_____ Two-gallon can of oil-gas mixture

_____ Small transistor radio

_____ Shark repellent

_____ Twenty square feet of opaque plastic

_____ One quart of 160-proof Puerto Rican rum

_____ Fifteen feet of nylon rope

_____ Two boxes of chocolate bars

_____ Fishing kit

LOST AT SEA: ANSWER AND RATIONALE SHEET

According to the "experts," the basic supplies needed when a person is stranded in mid-ocean are articles to attract attention and articles to aid survival until rescuers arrive. Articles for navigation are of little importance: Even if a small life raft were capable of reaching land, it would be impossible to store enough food and water to subsist during that period of time. Therefore, of primary importance are the shaving mirror and the two-gallon can of oil-gas mixture. These items could be used for signaling for air-sea rescue. Of secondary importance are items such as water and food, e.g., the case of Army C rations.

A brief rationale is provided for the ranking of each item. These brief explanations obviously do not represent all of the potential uses for the specified items, but rather the primary importance of each.

1. **Shaving mirror**
   Critical for signaling for air-sea rescue.

2. **Two-gallon can of oil-gas mixture**
   Critical for signaling--the oil-gas mixture floats on the water and could be ignited with a dollar bill and a match (obviously, outside the raft).

3. **Five-gallon can of water**
   Necessary to replenish loss by perspiring, etc.

4. **One case of U.S. Army C rations**
   Provides basic food intake.

5. **Twenty square feet of opaque plastic**
   Utilized to collect rain water, provide shelter from the elements.

6. **Two boxes of chocolate bars**
   A reserve food supply.

7. **Fishing kit**
   Ranked lower than the candy bars because "one bird in the hand is worth two in the bush." There is no assurance that you will catch any fish.

8. **Fifteen feet of nylon rope**
   May be used to lash equipment together to prevent it from falling overboard.

9. **Floating seat cushion**
   If someone fell overboard, it could function as a life preserver.

10. **Shark repellent**
    Obvious.

11. **One quart of 100-proof Puerto Rican rum**
    Contains 80 percent alcohol--enough to use as a potential antiseptic for any injuries incurred; of little value otherwise; will cause dehydration if ingested.

LAB SESSION 2: FLOW CHARTS

Lab Session 2: Flow Charts

The purpose of the Session Two lab is to give the students practice in constructing a flow chart of a NARF process. The process should be one with which the group is familiar. You may select the process ahead of time or allow the students to help in its selection.

This lab works best with two leaders--one person to moderate the discussion and another to draw the flow chart on a blackboard as it is defined by the students. These roles may be filled by a trainer and a class member, respectively.

When the leaders and the process have been chosen, begin by asking the students to identify the main steps of the process. Once this has been done, proceed to a more detailed description of each step, as time permits. After the lab, copy the flow chart from the blackboard and make a copy for each class member. Distribute and review before you begin the next session.

Since much of the benefit of flow charting comes from the exchange of information that occurs during its construction, it is important that all students are given a chance to participate in both the definition and discussion of the flow chart. This exercise will also give the students a chance to practice working as a team.

LAB SESSION 3: CAUSE-AND-EFFECT DIAGRAMS

Lab Session 3: Cause-and-Effect Diagrams

The purpose of the Session Three lab is to give the students practice in constructing a cause-and-effect diagram. The positive or negative effect should be one with which the group is familiar. You may select the effect ahead of time, or allow the students to help in its selection.

This lab works best with two leaders--one person to moderate the discussion and another to draw the cause-and-effect diagram on a blackboard as it is defined by the students. These roles may be filled by a trainer and a class member, respectively.

When the leaders and the effect have been chosen, begin by drawing the outline of a fishbone diagram on a blackboard. Allow the students to define the labels for the effect and main branch causes. Once this has been done, give each student a chance to suggest a possible cause under these main branches, filling them in on the diagram as they are suggested. After the lab, copy the diagram from the blackboard and make a copy for each class member. Distribute and review before you begin the next session.

Since much of the benefit of a cause-and-effect diagram comes from the exchange of information that occurs during its construction, it is important that all students are given a chance to participate in both the definition and discussion of the causes. This exercise will also give the students a chance to practice working as a team.

LAB SESSION 4: DATA COLLECTION

Lab Session 4: Data Collection Lab

1. What do we need to know?

   a. Determine purpose of data collection.

   b. Determine how data will be used.

      (1) Feedback

      (2) Understanding

   c. Types and sources of information that need to be gathered; for example, counts, frequencies, groups, individuals, other agencies, "experts" in the field.

   d. Ways in which information will be gathered (i.e., interviews, checksheets, existing data, computerized responses)?

   e. Format, that is, structure of the forms that will used to record information.

   f. Sampling plan--a schedule of when and how often data will be recorded and reported.

   g. Data collectors (e.g., supervisors, QA, artisans, trainers).

   h. Summarization and representation of data (choice of graphic tool).

2. Collect the DATA!

Lab Session 4: Practice Problem

We have a plating process involving 5 employees and 10 tanks of different chemical plating solutions. The percent of defectives has increased recently. We want to find out why this is occurring. What would be an appropriate data collection plan? What are the steps you would go through to find an answer to your problem? By what means would you collect and record your data? How would you graphically depict a summary of your data?

Lab Session 4: Steps to Take for Problem Solution

1. The PURPOSE would be to find the reason for the increase in the percent of defects. So we might be interested in which defects are most numerous, and which factors are "causing" the defects.

2. What will this information be used for? Will we change the situation or conditions to the extent that we can?

3. What will we need to know?

   a. Types of defects by frequency (i.e., rank order the types by how often they occur within a specified time period). You will need to determine the length of this period.

   b. Possible causes. We have information on the employees and the tanks. What else can we do?

      (1) Construct cause-and-effect diagram.

      (2) Possible factors: materials, maintenance, equipment age, work methods, training levels.

4. Decide what information we will gather and how it will be recorded.

5. Develop a sampling plan for data collection.

6. Determine who will collect the data. Make sure they understand what it is they will be recording and that they have the requisite training to make these judgments.

7. Ensure that identifying features of data collection will be obtained (i.e., dates, times, who collected the data, etc.).

Example of Data Collection Sheet

Frequency of Defects by Chemical Solutions

Date:
Section:
Inspector:
Total Number of Items Inspected:

*Defect	Nickel Part #	Cadmium Part #	Chrome Part #	Silver Part #	Other Part #	TOTAL Part #
Peeling						
Cracking						
Over-/Under-plating						
Fitting						
Fisheyes						
Burning						
Double-plating						
Shadowing						
Hardening						
Nodules						
Total						

*Other Areas of Interest

1. Day of Week
2. Worker

Number of Defects by Workers and Machines

Tanks	Workers				
	A	B	C	D	E
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

How might the above two data collection sheets be combined?

LAB SESSION 5: PARETO DIAGRAMS

Lab Session 5: Pareto Diagrams

The purpose of the Session Five lab is to give the students practice in constructing Pareto diagrams. Three examples are provided. You may use these examples or develop your own. All of the numbers are taken from actual slant-threes and handwrite data.

Begin the lab by working the calculations for the first problems with the help of the students. Encourage the students to compute the calculations on their own handouts while you demonstrate them on the blackboard. Complete the example by requesting a volunteer to graph the Pareto on the blackboard. The other students may use the graph paper provided to graph the example at their desks.

Allow the students the remainder of the lab period to compute the final two examples. While the students work, circulate throughout the room and give help with the calculations and graphing. Use the beginning of the next session to review the results of the final two examples.

Pareto Worksheet

Date: 12/20/84

Variable: Malfunction Code

Total Number Inspected = 191

Category	Number	Percentage	Cumulative Percentage
Plating Improper	69		
Paperwork Improper or Lost	64		
Tech Dir not Comp	37		
Burred	11		
Out of Tolerance	10		
Totals			

Notes. Some formulas helpful in computing a Pareto diagram:

1. Percentage for a category = number/total number inspected.

2. Cumulative percentage for a category = cumulative percentage for the category previous to it + percentage for that category.

Pareto Worksheet

Date: 12/20/84 Variable: Resp. Shop on Handwrite

Total Number Inspected = 185

Category	Number	Percentage	Cumulative Percentage
Plating	99		
Grinders & Hones	18		
Sandblasting	35		
Exam & Routing	19		
Cmpnts & Metal, Div	14		
Totals			

Notes. Some formulas helpful in computing a Pareto diagram:

1. Percentage for a category = number/total number inspected.

2. Cumulative percentage for a category = cumulative percentage for the category previous to it + percentage for that category.

Pareto Worksheet

Date: 12/20/84 Variable: Shop Initiating Handwrite

Total Number Inspected = 135

Category	Number	Percentage	Cumulative Percentage
Grinders & Hones	77		
Processing	7		
Sandblasting	26		
Rotor Heads	14		
Exam & Routing	11		
Totals			

Notes. Some formulas helpful in computing a Pareto diagram:

1. Percentage for a category = number/total number inspected.

2. Cumulative percentage for a category = cumulative percentage for the category previous to it + percentage for that category.

Pareto Worksheet

Date: Variable:

Total Number Inspected =

Category	Number	Percentage	Cumulative Percentage
Totals			

Notes. Some formulas helpful in computing a Pareto diagram:

1. Percentage for a category = number/total number inspected.

2. Cumulative percentage for a category = cumulative percentage for the category previous to it + percentage for that category.

LAB SESSION 6: HISTOGRAMS

Lab Session 6: Histograms

The purpose of this lab is to give the students practice in constructing histograms. Two examples are provided. You may use these or develop your own. All of the data are fictitious.

Example 1.

The data involve tank solution concentrations (ounces of deruster per gallon of water). These data represent possible concentrations measured at various intervals.

Example 2.

The data involve the amount of time it took to input a Handwrite, after it was initiated, into a computer. The value of "1" (one) day represents a Handwrite that was entered into the computer on the same day it was initiated.

Each of these examples contains worksheets designed to organize the data and provide the necessary formulas. Use the information on how to construct a histogram from Session Six to guide the class through the worksheets in the first example. A description of the three worksheets and some critical steps follow.

Histogram Worksheet One.

This worksheet contains the raw data for the example. Use the information on this form to fill in the blanks at the bottom of Worksheet One. X_L is the largest value identified. X_S is the smallest value in the data set. Compute the range.

EXAMPLE 1

HISTOGRAM WORKSHEET ONE

Variable: Ounces of deruster per gallon of water.

Data Values						
41.85	44.45	51.30	50.85	48.60		
50.85	41.85	46.35	46.94	41.85		
51.30	43.65	40.95	35.51	45.00		
33.30	44.61	49.50	40.33	46.80		
42.75	44.12	48.60	47.70	31.50		
44.10	34.45	44.10	47.25	57.60		
47.70	43.36	53.55	47.70	38.25		
53.10	54.45	48.60	40.51	39.95		
39.15	47.25	39.15	40.50	57.60		
34.20	50.40	47.70	37.35	53.23		

Specification Limits: 40-48 oz./gal.

Total number of data values observed (N) =

X_L =

X_S =

Range = $X_L - X_S$

EXAMPLE 1

HISTOGRAM WORKSHEET TWO

Formulas and Tables Helpful in Computing a Histogram

Number of Data Values Observed	Number of Intervals (K)
Under 50	5-7
50-100	6-10
101-250	7-12
Over 250	13-20

Range = $X_{large} - X_{small}$

To computer the class interval: H = range/K-1

N =

Range =

Number of intervals (K) =

Interval size (H) =

EXAMPLE 1

HISTOGRAM WORKSHEET THREE

Class Boundaries and Frequencies

Class Number	Class Boundaries Lower	Class Boundaries Upper	Frequency Tally	Frequency
			Total	

N =

Range =

Class interval size (K) =

EXAMPLE 2

HISTOGRAM WORKSHEET ONE

Variable: Lag Time from Initiation on Hardwrite to Entry on the Computer (Days)

Data Values						
1	3	2	2	2		
1	2	1	1	2		
4	2	5	1	7		
2	1	3	1	20		
1	7	2	1	9		
2	4	2	1	6		
2	4	1	3	4		
2	3	3	4	3		
5	1	6	5	2		
5	2	8	10	2		

Specification Limits:

Total number of data values observed (N) =

X_L =

X_S =

Range = $X_L - X_S$

Same day lag time is considered to be "1."
Next day lag time is considered to be "2."

EXAMPLE 2

HISTOGRAM WORKSHEET TWO

Formulas and Tables Helpful in Computing a Histogram

Number of Data Values Observed	Number of Intervals (K)
Under 50	5-7
50-100	6-10
101-250	7-12
Over 250	13-20

Range = $X_{large} - X_{small}$

To computer the class interval: H = range/K-1

N =

Range =

Number of intervals (K) =

Interval size (H) =

EXAMPLE 2

HISTOGRAM WORKSHEET THREE

Class Boundaries and Frequencies

Class Number	Class Boundaries Lower	Upper	Frequency Tally	Frequency
			Total	

N =

Range =

Class interval size (H) =

LAB SESSION 7: SCATTER DIAGRAMS

Lab Session 7: Scatter Diagrams

The purpose of this lab is to give the students practice in constructing scatter diagrams. Two examples are provided. You may use these or develop your own. All of the data are fictitious.

Example 1.

The data for this example give the speed of a conveyor (X variable) and the length of threads (Y variable) as they move along the conveyor. The data pairs in the table were collected over a 1-week period.

Example 2.

The data for this example give the number of months of training a worker received (X variable) and the number of errors the worker made on a training-related task (Y variable). The data pairs in the table were collected over a 1-month period.

Begin the lab by helping the class to graph the first example. After the pairs of points have been plotted (be sure axes are properly labeled), draw in an approximate "line of best fit." Allow the students the remainder of the lab period to complete the final example.

While the students work, circulate throughout the room and give help with the graphing. Use the beginning of the next session to review the results of the examples. At this time, have the students identify the type of correlation indicated by the "line of best fit."

SCATTER DIAGRAM WORKSHEET

EXAMPLE 1

X Variable (Horizontal Axis) = Conveyor Speed (cm/sec)
Y Variable (Vertical Axis) = Severed Length of Threads (mm)

X Variable	Y Variable	X Variable	Y Variable
8.1	1046	8.0	1040
7.7	1030	5.5	1013
7.4	1039	6.9	1025
5.8	1027	7.0	1020
7.6	1028	7.5	1022
6.8	1025	6.7	1020
7.9	1035	8.1	1035
6.3	1015	9.0	1052
7.0	1038	7.1	1021
8.0	1036	7.6	1024
8.0	1026	8.5	1029
8.0	1041	8.0	1031
7.2	1029	7.5	1015
6.0	1010	5.5	1023
6.3	1020	8.0	1030
6.7	1024	5.2	1010
8.2	1034	6.5	1025
8.1	1036	8.0	1030
6.6	1023	5.2	1010
6.5	1011	6.5	1025

SCATTER DIAGRAM WORKSHEET

EXAMPLE 2

X **Variable** (Horizontal Axis) = Number of Months of Training
Y **Variable** (Vertical Axis) = Number of Errors Made in Previous Month

X Variable	Y Variable	X Variable	Y Variable
3	5	3	3
4	6	1	8
7	2	4	7
5	3	11	3
4	2	12	2
4	6	4	3
3	6	1	7
8	3	3	6
5	4	7	4
2	8	10	1
9	1	7	4
3	7	5	3
12	2	4	4
4	6	4	2
5	5	3	5
3	8	8	2
9	1	5	3
6	2	2	9
5	3	3	6
4	2	3	9

Fictional Data

SCATTER DIAGRAM WORKSHEET

X Variable (Horizontal Axis) =
Y Variable (Vertical Axis) =

X Variable	Y Variable	X Variable	Y Variable

LAB SESSION 8: RUN CHARTS

Lab Session 8: Run Charts

The purpose of this lab is to give the students practice in constructing run charts. Five examples, each based on a different measure, are provided. You may use these examples or develop your own. All of the data are fictitious.

In order to construct the run charts, you must calculate:

1. The frequency (freq.) or the total of each day's production.

   Example: For day 4, the frequency is found by adding up the products made by each of the five workers, or 28 + 23 + 28 + 23 + 26 = 128.

2. The mean ($\bar{x}$) or average daily production of the workers.

   Example: For day 4, the mean equals the frequency of production (128) divided by the number of people working (5), or 128/5 = 25.6. This indicates that the workers averaged 25.6 products on day 4.

3. The range (R) or difference between the highest versus the lowest performance for each day.

   Example: For day 4, the range is equal to the highest production (28) minus the lowest production (23), or 28 - 23 = 5.

4. The number of defective products (NP) for each day.

   Example: For day 4, the number of defective products is found by adding up the number of defective products made by each worker, or 5 + 3 + 0 + 3 + 5 = 16.

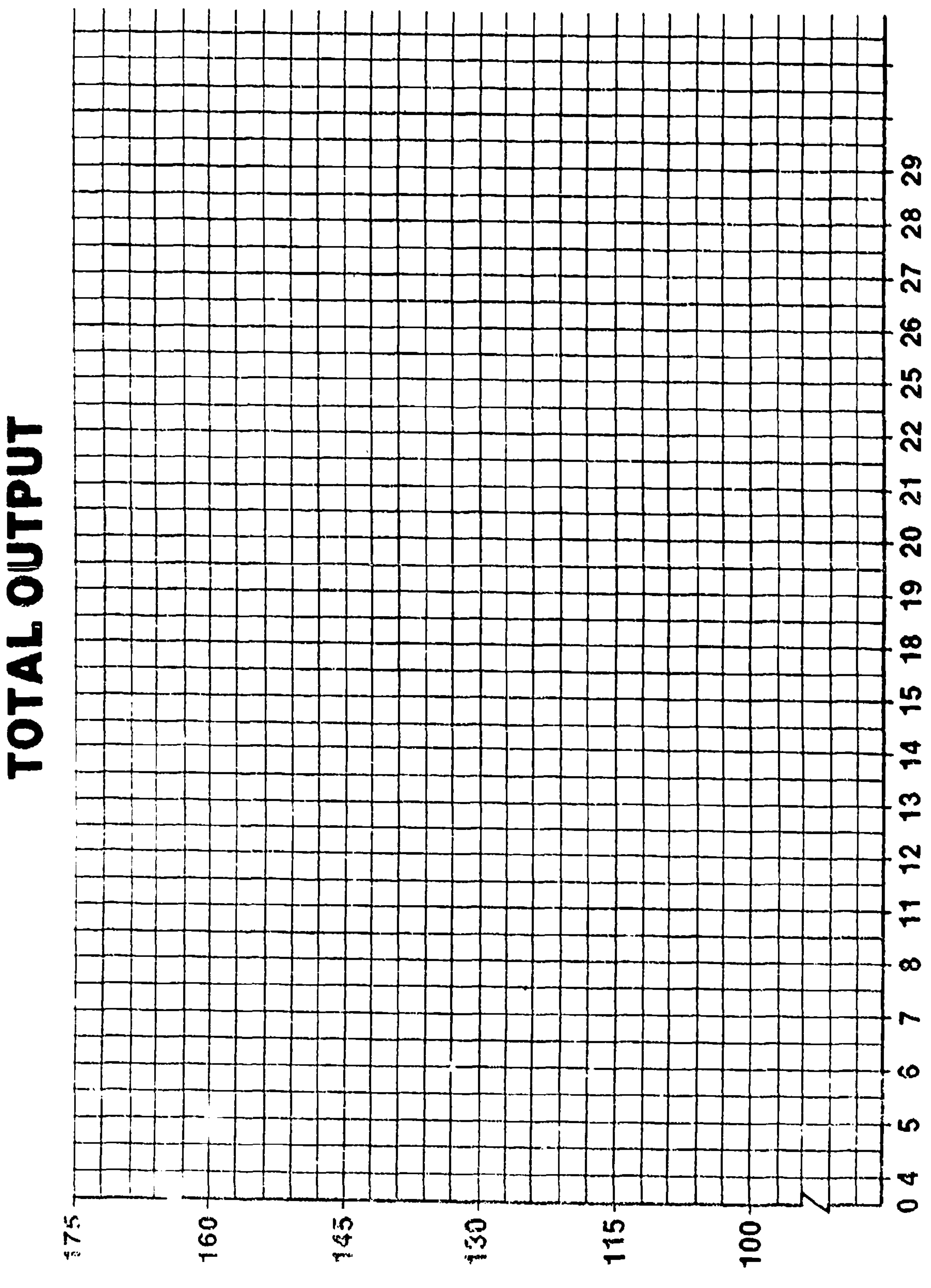
Defects found in gizmos produced in shop XX
for the period of March 4-29, 1986

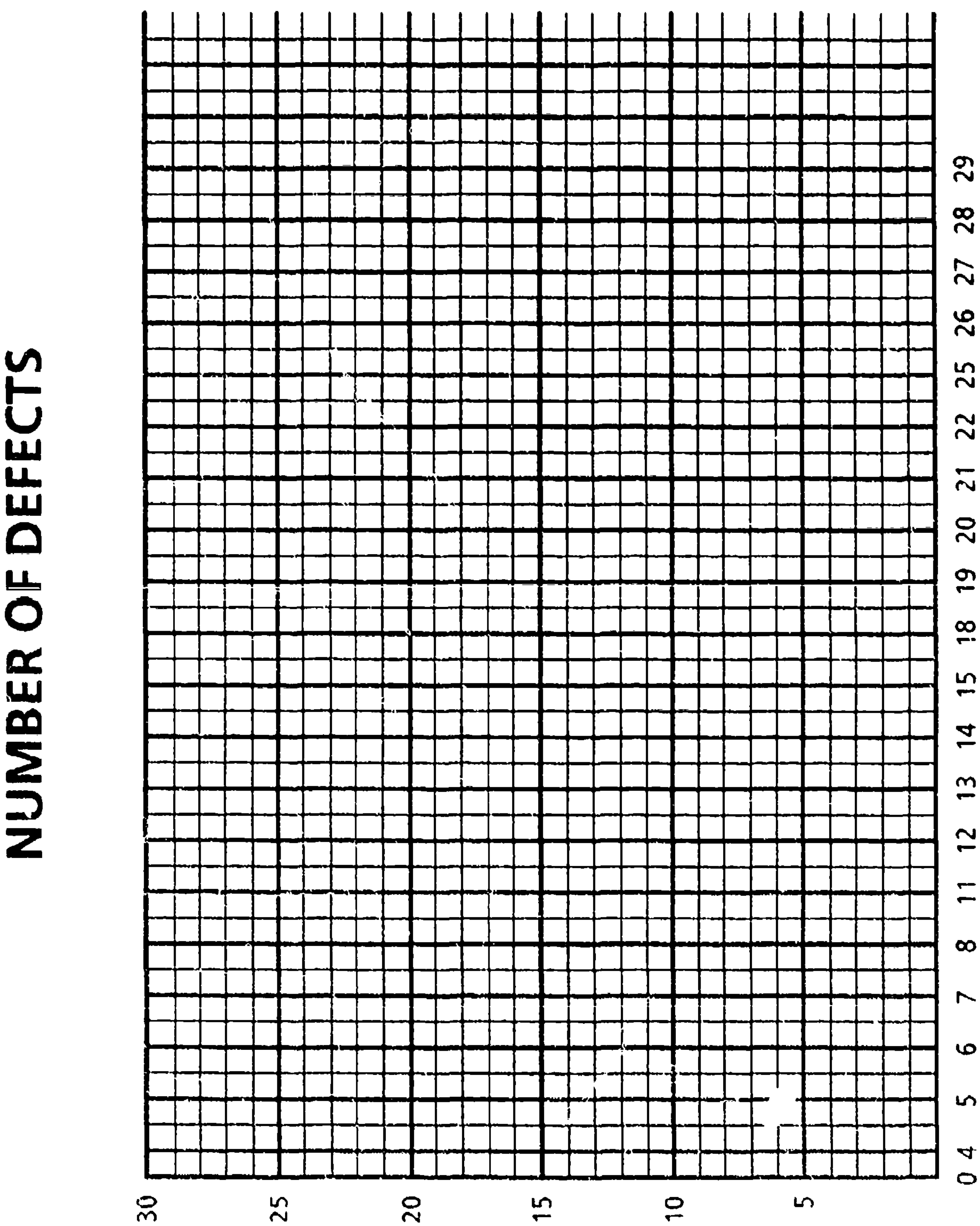
DATE	OPERATORS				
	A	B	C	D	E
4	5	3	0	3	5
5	2	3	1	5	5
6	2	3	0	1	2
7	5	3	3	2	2
8	1	2	2	2	3
9	X	X	X	X	X
10	X	X	X	X	X
11	1	2	0	4	4
12	3	2	2	4	4
13	1	4	1	4	4
14	4	4	4	2	2
15	4	2	3	3	4
16	X	X	X	X	X
17	X	X	X	X	X
18	1	0	1	0	1
19	0	1	3	2	1
20	4	3	3	1	1
21	3	2	4	1	0
22	3	4	0	5	2
23	X	X	X	X	X
24	X	X	X	X	X
25	1	4	1	4	3
26	2	1	1	4	3
27	2	1	4	2	0
28	4	3	4	1	1
29	0	4	1	1	3

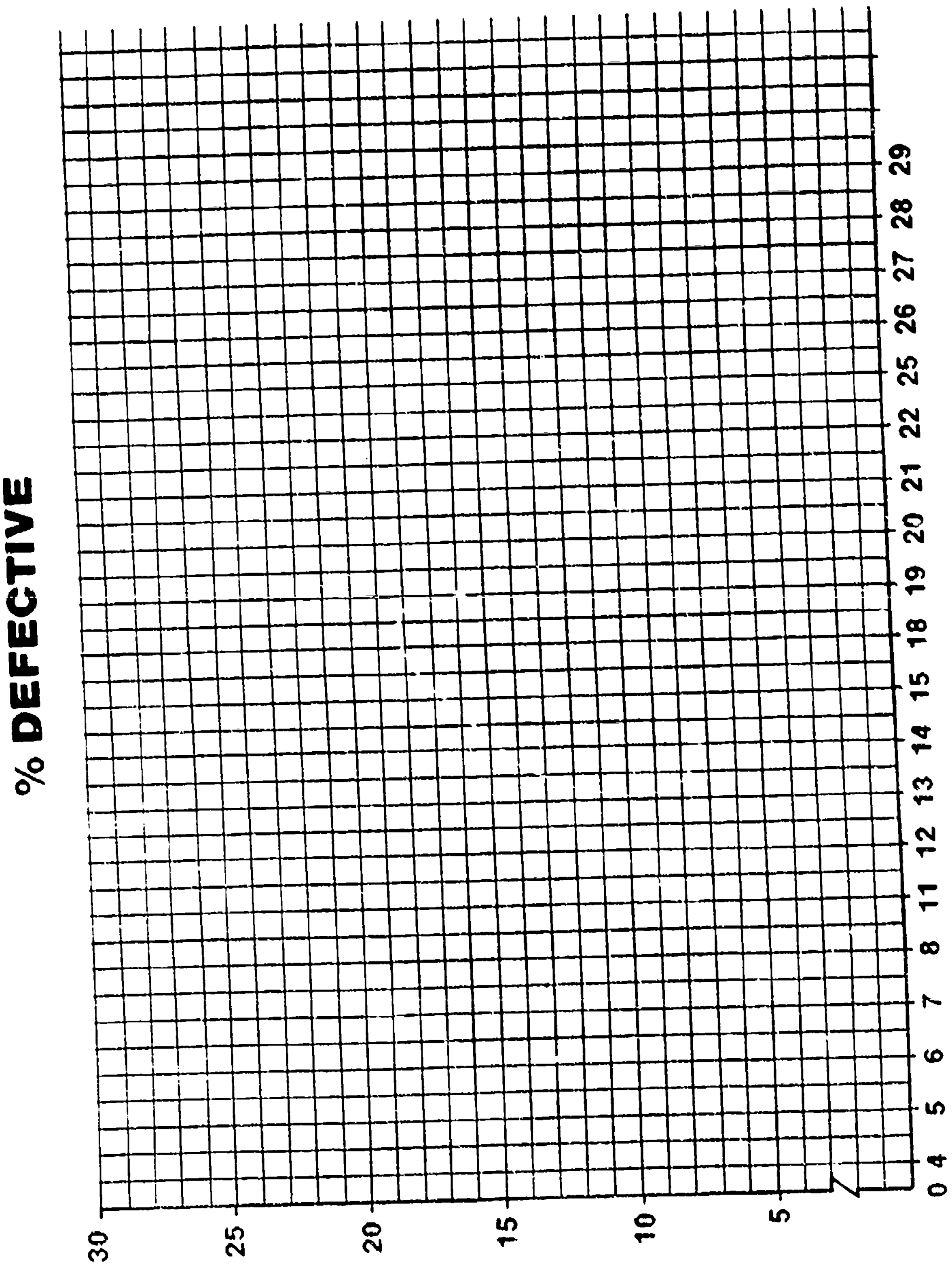
Production in gizmo shop XX
for the period of March 4-29, 1986

DATE	OPERATORS				
	A	B	C	D	E
4	28	23	28	23	26
5	29	26	29	21	38
6	35	25	26	23	21
7	32	26	35	19	38
8	38	25	32	17	35
9	XX	XX	XX	XX	XX
10	XX	XX	XX	XX	XX
11	33	20	22	18	21
12	27	23	29	24	30
13	22	28	26	15	32
14	29	23	28	25	31
15	37	20	21	20	35
16	XX	XX	XX	XX	XX
17	XX	XX	XX	XX	XX
18	22	20	24	18	39
19	24	26	24	24	42
20	32	22	20	20	40
21	38	29	25	18	40
22	35	23	27	20	41
23	XX	XX	XX	XX	XX
24	XX	XX	XX	XX	XX
25	32	26	21	16	47
26	29	24	30	18	46
27	33	29	29	18	49
28	37	24	27	24	46
29	39	27	30	14	51

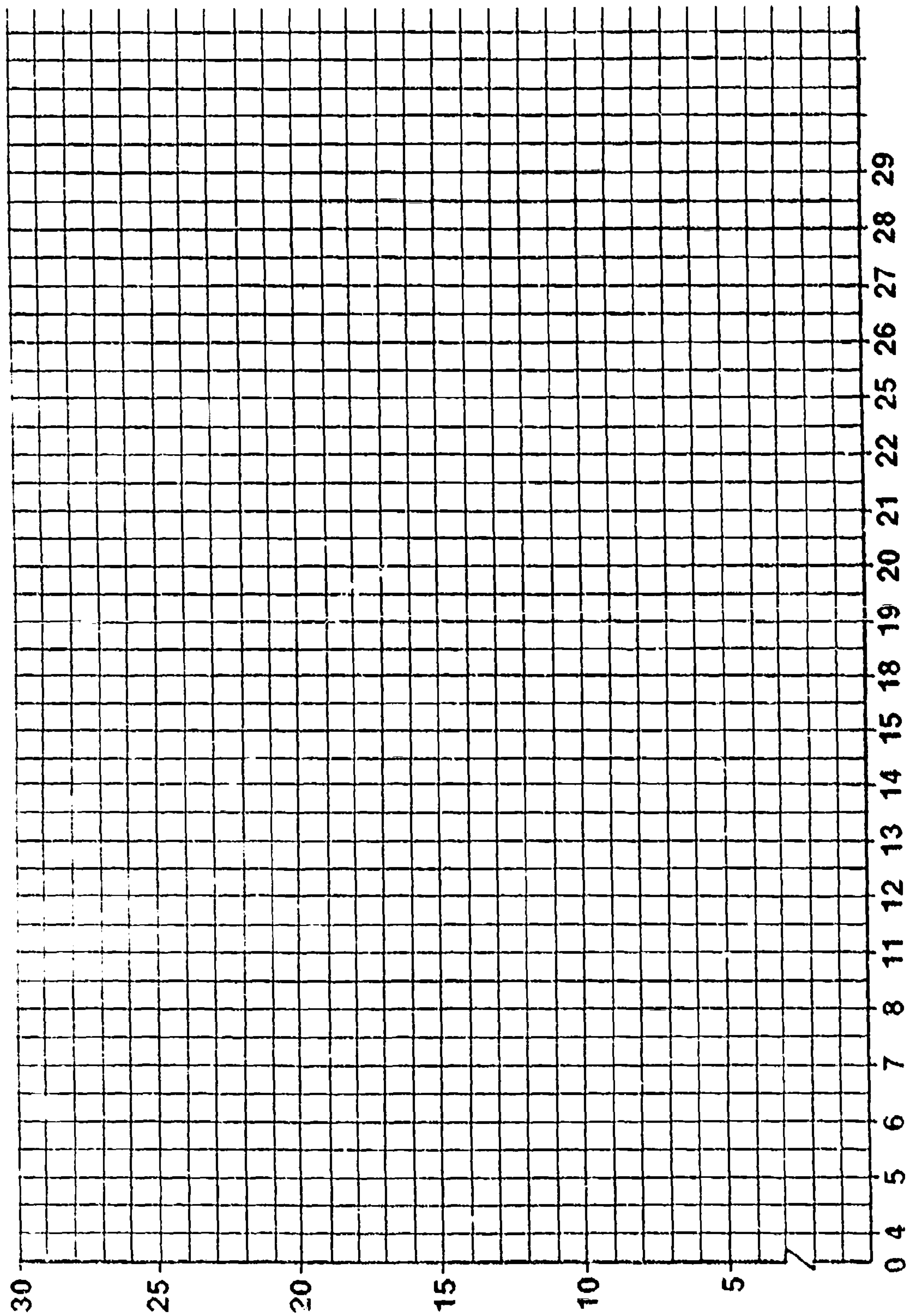
	Freq.	$\bar{X}$	R	NP	% Defective
DATE					
4					
5					
6					
7					
8					
11					
12					
13					
14					
15					
18					
19					
20					
21					
22					
25					
26					
27					
28					
29					


TOTAL OUTPUT
175
160
145
130
115
100
0 4 5 6 7 8 11 12 13 14 15 18 19 20 21 22 25 26 27 28 29

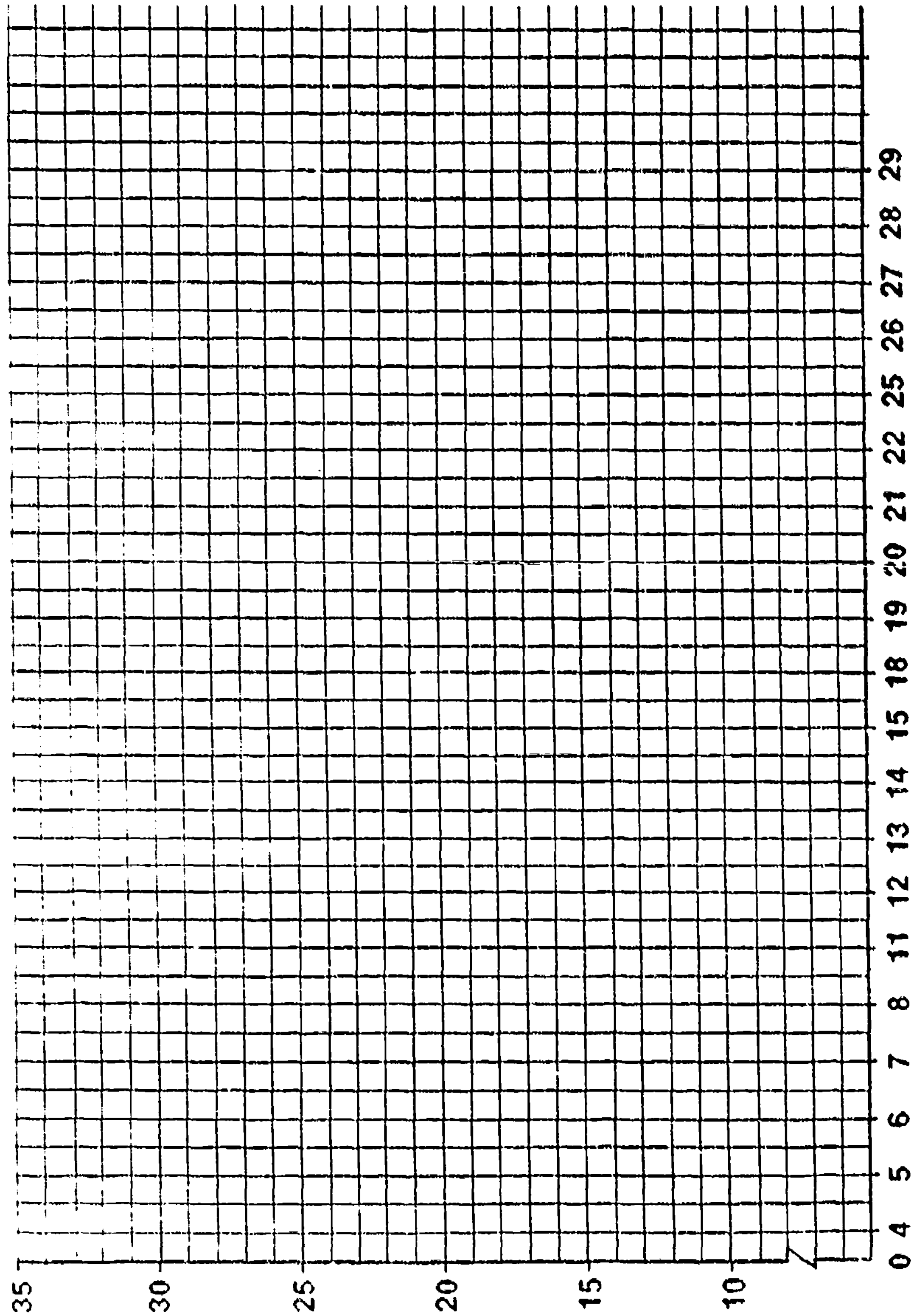

NUMBER OF DEFECTS
30
25
20
15
10
5
0 4 5 6 7 8 11 12 13 14 15 18 19 20 21 22 25 26 27 28 29


% DEFECTIVE
30
25
20
15
10
5
0 4 5 6 7 8 11 12 13 14 15 18 19 20 21 22 25 26 27 28 29

RANGE



AVERAGE OUTPUT



LAB SESSION 9: CONTROL CHARTS

Lab Session 9: Control Charts

This lab presents an overview of control charts and does not emphasize computation. It does not include a lab to give students practice in constructing control charts. You may wish to use this time to discuss the flow chart that follows. The flow chart describes the process within the Act stage of the PDCA cycle. Until now, we have not mentioned the activities that occur in the Act phase. Be sure to emphasize the importance of the implementation and testing of possible solutions developed by the project team. The flow chart includes a decision point at which time the team must decide if a solution needs to be passed up to a higher level quality board for action. The discussion of this chart may be used as an introduction to the final session that deals with the structure and relationships of quality teams.

Following the flow chart are two sets of instructions for the calculation of control charts. Distribute these to your students for future reference.

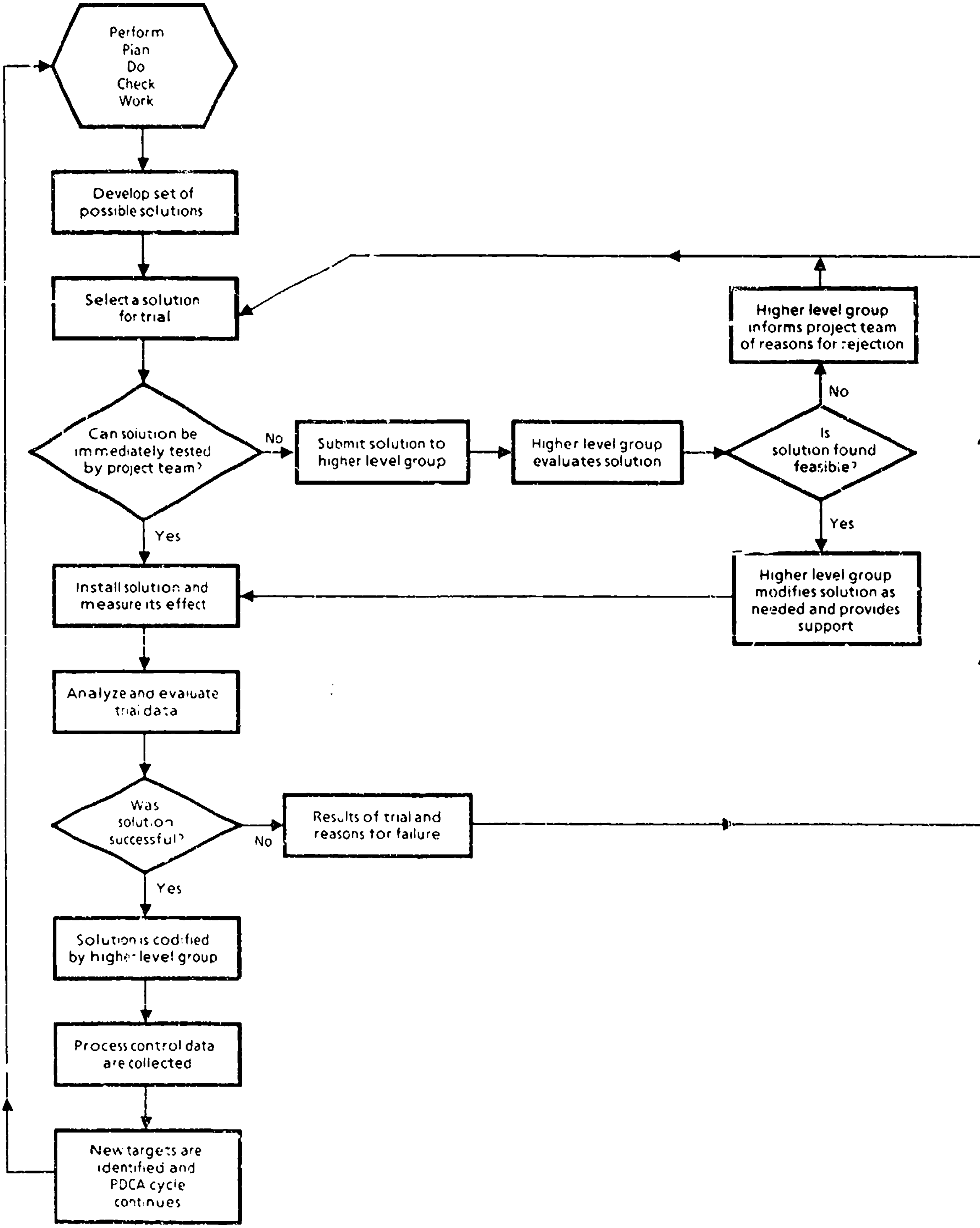


Figure 9-1. Flow chart displaying the Act stage of the PDCA cycle.

Definitions and Symbols for $\bar{x}$ and R Charts

x = An individual reading for observation.

n = The number of observations in a group, often known as the sample size. The sample size may be 2, 3, 4, 5, or more, but no greater than 10.

$\bar{x}$ (x bar) = The average of a group of x's. The $\bar{x}$ is calculated by the formula:

$$\bar{x} = \frac{x1 + x2 + x3 \ldots xn}{n} \quad \text{or} \quad \frac{\text{sum of sample subgroup}}{\text{sample size}}$$

$\bar{\bar{x}}$ (x double bar) = The average of a series of $\bar{x}$ values. The $\bar{\bar{x}}$ is calculated by the formula:

k = Number of groups in a sample:

$$\bar{\bar{x}} = \frac{\bar{x}1 + \bar{x}2 + \bar{x}3 \ldots \bar{x}n}{k} \quad \text{or} \quad \frac{\text{sum of sample means}}{\text{number of sample groups}}$$

R (range) = The difference between the largest and the smallest reading in the sample.

R = Largest x - smallest x.

$\bar{R}$ (R bar) = The average of a series of R values.

$$\bar{R} = \frac{R1 + R2 + R3 \ldots rn}{k} = \frac{\text{sum or ranges}}{\text{number of sample groups}}$$

A_2 = A factor used in calculating the control limits for the $\bar{x}$ chart.

D_4 = A factor used in calculating the upper control limit for the R chart.

D_3 = A factor used in calculating the lower control limit for the R chart.

The factors A_2, D_4, and D_3 vary with the size of the sample. A table of factors is provided in the material on computing $\bar{x}$ and R charts.

Calculation of $\bar{x}$ and R Charts

As stated earlier, the $\bar{x}$ and R charts are used together to monitor process performance. The following material gives a general outline of how the $\bar{x}$ and R charts are calculated. For detailed information, refer to the Ishikawa textbook (1985), pages 66-70. Here are the steps for calculating $\bar{x}$ and R charts.

1. Collect the data. The total sample size should consist of 100 or more measurements.

2. Arrange the data into subgroups of two to five measures each. Sample subgroups are usually arranged according to such factors as time, date, lot, operator, equipment, etc. The number of measures in a subgroup determines the size of the subgroups. Size is represented by the letter n. The number of subgroups in a sample is represented by the letter k.

3. Record the data on a data sheet. The data sheet should be designed so that it is easy to compute values of $\bar{x}$ and R for each subgroup.

4. Compute the means or $\bar{x}$ for each subgroup. Add the measures within a subgroup and divide the sum by the subgroup size (n).

5. Compute the range or R for each subgroup. The range for a subgroup is found by subtracting the lowest measurement from the highest measurement.

6. Compute the overall means or $\bar{\bar{x}}$. Add the means of all the subgroups and divide the sum by the number of subgroups (k).

7. Compute the average value of the range (R) by adding the ranges of all the subgroups and dividing the sum by the number of subgroups (k).

8. Compute the control limit lines. The factors A_2, D_4, and D_3 refer to values that change depending on subgroup size. Those values are presented in the following table:

Table of Control Chart Coefficients

n	A_2	D_4	D_3
2	1.880	3.267	-- Do not apply
3	1.023	2.575	Do not apply
4	0.729	2.282	Do not apply
5	0.577	2.115	Do not apply
6	0.483	2.004	-- Do not apply
7	0.419	1.924	0.076

LAB SESSION 10: QUALITY TEAMS

HWSO PROJECT TEAM

Date: ________

Member	Code	Present	Substitute	Code
Rick James*	56140	X		
Tom Williams	56340	X		
Chris Thompson	57230	X		
Robin Stevens	62110	X		
Jim Palmer	62120	X		
Ed Daley	63310		Jack Larsen	63310
Terry Mason	97311	X		
Tony Gerra	97211	X		

SUMMARY AND ACTION ITEMS

Reviewed report of study regarding HWSOs conducted by Code 232 (3 August 1983).

Listed causes for writing a HWSO in E & R:

- Jobs without documentation
- Repair jobs without decks (nonroutine)
- No link on Wip (many reasons)
- Lost paperwork
- Additional work (3Rs)
- Paperwork out of sync
- Customer service jobs (routine and nonroutine)
- Subgroup from feeder shop

Peter Landers reported results of recent study conducted on HWSOs.

Reasons for HWSOs are not clearly listed on form.

ACTION: T. Williams, R. Stevens, and C. Thompson will organize a log to be completed in E & R when HWSO is written. Log will include link number, program, and reason for writing.

The possibility of producing a new MDR deck when one was unavailable was discussed.

ACTION: R. James will look into the feasibility of issuing new decks.

*These names are fictitious.

PROGRESS REPORT

Team: Plating Team

Date: July 31, 1985

Subject: Anode Cleaning in Chrome Tanks

Objective:

Maintain clean utility anodes for the purpose of obtaining better current.

Action Codes:

*Allen Jones--34200
Tony Benson--61300
James Peterson--97324

Analysis:

- New utility anodes are difficult to pull and clean (4' long, lead).
- Anodes are cleaned infrequently (about every 6 months).
- Heavy deposits of lead salts build on anodes after extended use without cleaning--leads to bad current and contributes to bad plating. Oxides build up in tanks. Anodes shrink.
- Anodes require sandblast cleaning.
  About 50 percent of anodes are no good and must be thrown away.
  Lead goes into sand and sand must be changed.
  When anodes are cleaned, tanks are down for days or weeks.
- Cleaning standards are vague.

Plan of Action:

- Contact other plating facilities.
- Test anode cleaner/steam clean method.
- Clean anodes put in all chrome tanks.
- Pull and clean anodes every 6 weeks.

Person Contacted:

Fred Jones, McClellan AFB*
Mr. McMichael, NARF Norfolk

---

*The names listed in this example are fictitious.

Information Obtained:

- Twenty-six anodes were cleaned using new method. All cleaned up.
- Other facilities have some problems.

Action Taken:

- For present time, pull anodes every 6 weeks and clean with two-stage process. Bulletin board will be made for shop to show anode change schedule.
- Keep spare anodes to replace others being cleaned.
- To make cleaning process easier for shop personnel, move tank P8-7 behind chrome tanks and use for cleaning solution. Move tank P8-8 next to it and equip it with air-water power spray. (P8-7 and P8-8 are currently scheduled for removal.)

Recommendation:

- For the future, look into what is the optimal time period for cleaning utility anodes. Six weeks is an arbitrary time period.

Potential Problems:

At this time, moving the tanks in the shop is Priority 3 and may take a couple of years to accomplish.

GLOSSARY

GLOSSARY

Cause-and-effect diagram: A diagram that shows the different factors or causes of a certain effect and how they interrelate.

Central tendency: The typical or representative score in a group of scores. Measures of central tendency include the mean, median, and mode.

Continuous data: Data that are measured; for example, length, width, time, and temperature.

Control chart: A graph that compares samples of process performance to a statistically predicted range of performance.

Control limits: Statistical estimates of how a process should perform under stable conditions.

Correlation: A measure of the degree of relationship between two variables.

Data: Information collected in a systematic and objective manner to answer a specific question or set of questions.

Discrete data: Data that are based on counting (e.g., number of defects, types of defects, sex of workers, number of injuries per shop).

Dispersion: How data are positioned around their central value. Some measures of dispersion are range and spread.

Distribution: The arrangement of a set of data according to frequency, time, or location. A distribution can visually summarize qualities of the data such as dispersion, peakedness, and skewness.

Flow chart: A diagram that depicts the steps in a process and how they interrelate.

Frequency: The number of times an event is observed.

Histogram: A vertical bar graph that depicts the distribution of a set of continuous data.

Normal curve: The shape of a distribution that resembles a bell. A distribution curve that is normal is symmetrical in appearance.

Normal variation: Random differences that are a natural part of any system, procedure, or operation.

PDCA Cycle: The Plan-Do-Check-Act cycle of continuous improvement developed by Shewhart and Deming.

Pareto diagrams: A vertical bar graph that displays categories in decreasing order of frequency from left to right.

Pattern interpretation: Using the placement of data points on a control chart to determine if a system is in or out of control.

Peakedness: A measure of the height of a distribution that describes its flatness or curve.

Population: All possible units with defined characteristics.

Process: The operations and resources contained within a particular stage of a system.

Process in control: The state arising when the production process is stable and there is no abnormality in the points on the control chart.

Process out of control: The state arising when the production process is not stable and there are points outside the control limits on the control chart.

Quality: A characteristic or the value of a product. It is a factor of the appropriateness of the design and specifications and the adherence to these specifications in production.

Random sampling: Sampling from a population such that each unit has an equal chance of being selected for the sample.

Run chart: A run chart is a line graph that shows data plotted over time.

Sample: A subset of units taken from a population or a group of measures taken from the overall output of a process or a system. Samples are used to estimate overall performance and quality of an output.

Sample subgroup: Samples divided into small units in order to show the effect of a particular factor or set of factors.

Sampling technique: The way a sample is selected from a population, i.e., random or stratified.

Scatter diagram: A diagram that shows the relationships between two variables that have been measured in pairs.

Skewness: A bunching of data on one side of distribution.

Special variation: Nonrandom variation that indicates specific problems in a system, procedure, or operation.

Spread: The width of a histogram. The more narrow the spread, the more uniform the product or service.

Stratified sampling: Sampling from different parts of a population in the same proportion that they occur in that population.

Structured problem solving: A group approach to solving problems. It involves identifying problems in a systematic way, suggesting solutions to them, and determining the effect of implementing them.

System: A set of procedures and resources that work together to produce a given service or product.

Variable: Sometimes called a measure, it is a general name for anything being measured.

Variation: Differences in units or the measure of units due to errors in materials, machines, manpower, or methods. The more variation, the less uniform the unit.

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BIBLIOGRAPHY

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